Association of British Manufacturers of
Agricultural Chemicals

BRITISH INSECTICIDE & FUNGICIDE CONFERENCE 1961

PROCEEDINGS

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BRITISH INSECTICIDE AND FUNGICIDE CONFERENCE

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OPENING ADDRESS

by The President, Dr. H.G.Sanders

Ministry of Agriculture, Fisheries and Food

Before we plunge into the highly technical matters we are to discuss I have been given the chance to say a brief word of welcome. It is certainly very encouraging to those who have organised this Conference that we have so large and representative a gathering, which will ensure that this will be an Event of great importance to agriculture and to the chemical industry. Year by year farming comes to rely more and more on chemical controls and it must be very right that we should get together for discussion of the position reached and of the hopes and ideas germinating in the minds of research workers. We are, of course, going to be a bit scientific but we include advisory people whose job it is to interpret science to practical men, to pick out the knowledge which is ripe for application and to pass it on to farmers.

Many here today have been at the B. W. C. C. Conferences. I have to confess that at those I've often found myself out of my depth. Here I can hardly expect to have my foot on the bottom at all for the problems confronting us now are more complex and, indeed, are fraught with greater hazard. There are always exceptions, but generally speaking herbicides are relatively harmless to man and to animals and are non-persistent. One of the first things we hear of when we start learning biology is seed dispersal; nevertheless weeds tend to stay put or to spread slowly. The position is very different with insects and fungi. They are more mobile and hence the need for chemicals which will see the protected plant through the period when it is at risk. Some of the chemicals with considerable biological efficiency against insects and fungi unfortunately have high mammalian toxicity. This has led to considerable unease in the public mind. Part of this arises from the really surprising ignorance which exists of the safeguards which protect the public from harm, and we ought to do all we can to remedy this state of affairs. There are some pretty high hurdles that have to be cleared before a new chemical gets into common use and that these are effective is shown by the lack of evidence of any harm suffered by consumers of crops which have had chemicals applied to them. The same, indeed, can be said in regard to those who apply the chemicals; it is true that very occasional tragedies have occurred but they have been due to carelessness and their numbers have been infinitesimal compared to the fatalities and injuries suffered through carelessness with hazards other than chemical ones. Concern over dangers to wild life is widespread and I think we can understand it, but the idea which some people have, that indiscriminate slaughter is going on all the time, is very wide of the mark. When it was established that some very efficient seed dressings were causing deaths to birds the Government and Industry agreed on restrictions which, there is every reason to hope, will stop these deaths. It is easy enough to argue that if proper precautions had been taken earlier

no deaths would have occurred at all but laboratory tests and field trials cannot reveal every hazard that could arise under any farming conditions to the almost infinite variety of wild life. The Notification Scheme now requires data on wild life and ensures that every possible care will be taken in the future, but only the general use of a new chemical can show whether or not it presents any hazard at all to wild life. No irreparable harm has been, or is likely to be, done but there is clearly a need for unceasing vigilance and this will be forthcoming. It is quite silly to accuse the scientist of heartless disregard for any other organism in his efforts to control a particular pest. He must in addition to wild life always give careful thought to beneficial organisms such as pollinators and predators.

The complexity of this Conference's subject is evident from a glance at the title of the papers we are to hear. The field they cover is very wide but no-one would claim that every conceivable aspect is included. We have here representatives of industry, government departments, research institutes and universities, and I am quite sure that getting all you people together is, in itself, a very good thing. It is a happy state of affairs that in this field there is a spirit of cooperation, of which this Conference is a manifestation. I had another example of this spirit earlier this year. A Research Study Group, of which some of you may have heard, wanted to know what acreage of the U. K. was sprayed with chemicals which are generally recognised to be toxic - don't ask me to define "toxic" because I defy anyone to produce a satisfactory definition. I wrote to all the companies in the country which manufacture, formulate or import pesticides and I asked a good deal of them. What I asked was, in terms of "acres sprayed", the amounts of certain specified chemicals they sold in 1955 and in 1960. Needless to say I would not have done this unless Mr. Mellor and Mr. Williams had first prepared the ground for me and naturally I regard the information I got as highly confidential; no-one, apart from my secretary and myself, has seen the replies and all that will see the light of day are four totals from which it is quite impossible to deduce what any one firm sold of any chemical. I had a reply from every single firm to whom I wrote and, where they were concerned with the particular chemicals, the figures for which I asked. It really is something to get 100 per cent replies from a round robin but what particularly impressed me was the care taken, by correspondence between themselves, to ensure that there was no duplication in the figures. I gladly seize the chance, here and now, publicly to thank all my correspondents for the considerable trouble they took and in particular the President, Secretary and all in ABMAC who made this little enquiry possible. The results were interesting and I felt they justified the whole exercise. They showed that the acreage sprayed with these toxic chemicals had more than doubled in the 5-year period but that there had been a very marked shift towards the less toxic materials. This is very encouraging because it is so clearly the way we must go. Research workers in this field do not need to be told that we want effective chemicals of lower mammalian toxicity; they are straining every nerve to this end and the figures I collected show that they are achieving considerable success.

Much effort has gone to organising this Conference and the attendance shows that this preliminary work has been well done. I am entirely confident that our meeting is going to prove interesting and useful.

THE EELWORM PROBLEM

by F. G. W. Jones

Rothamsted Experimental Station

Although infested glasshouses and nurseries can be successfully treated with soil fumigants, only exceptionally are treatments for controlling nematodes in field crops in Great Britain economic. In the U.S.A., many thousands of acres of land are treated annually, mainly in the S.E. coastal plain, but the cash value of the crops concerned is greater and the soil temperatures appreciably higher. Although much screening and many ad hoc experiments are done each year, the results of which present a conflicting mixture of science and sales pressure, only three soil nematicides have stood the test of time: bromomethane, dibromoethane and dichloropropene. Dibromochloropropane and some of the dithiocarbamates and their relatives and one or two phosphorus compounds related to parathion show promise. The chemicals listed in Tables 1 and 2 are all "broad band" toxicants, harmful to plants and to mammals. Their undesirable properties are mitigated to some extent where field dosage rates are low as for mercury and dibromochloropropane (Table 1). With the exception of (3) in Table 3, all chemicals in the parathion group are highly toxic to mammals though usually of low toxicity to plants.

Effective chemicals are few partly because of the rather intractable problems posed by nematode control. Nematodes are rarely exposed as are many insects. No thorough and concerted attempts have been made to employ chemicals against species of Ditylenchus (stem and bulb eelworms), Aphelenchoides (bud and foliar nematodes) or Anguina (seed gall nematodes) although the difficulties are less than in the control of nematodes in soil, where most noxious nematodes occur.

For annual field crops the aim is to reduce the eelworm population in the soil occupied by plant roots below the level that does economic damage. Eradication is out of the question for vast amounts of chemical would be necessary and reinfection would probably occur from deep down below. Highly phytotoxic chemicals can be used in the interval between crops, provided they do not persist too long, and control has to be exerted to a depth which is equal to, or perhaps slightly below plough depth. Some economy can sometimes be achieved for crops with wide row spacing by confining treatment to the actual row. For perennial crops or plantations, phytotoxic compounds can be used only before planting and in the intervals between replacement. Tree roots often penetrate deeply and, in porous soils, as in the citrus orchards of Florida, nematodes may be more abundant six feet down than in the surface. The problem of disinfestation to that depth is so formidable that an entirely different approach seems necessary. Even for arable land the weight of soil to be treated to plough depth is of the order of 1,000 tons per acre including some 200 tons of water.

Because of the great mass of soil to be treated and the difficulties of

mixing materials intimately with it, all the successful nematicides used so far possess appreciable vapour pressures and so are self-dispersing in treated soils. Spot or strip injections are commonly used and spaced so as to give confluent zones of adequate kill within the soil. Nematicides formulated as granules, as drenches or mixed directly into the soil attempt the same object in a different way. The situation after they are introduced is illustrated in Fig. 1. For most ordinary soils in reasonable tilth there is no difficulty in securing diffusion through the major pores. The main resistance arises in the smallest pores and channels leading to the interior of aggregates and crumbs and some of the losses occurring en route are depicted.

Many factors affect fumigation of field soils. Soil temperature greatly influences vaporisation and rate of diffusion. High temperatures assist fumigation but may lead to too rapid loss of gas from the surface. Fumigants with low boiling points and low vapour pressures are unsuitable for cold soils which, especially when wet, may retain gas partly in solution and lead to enhanced and long continued phytotoxicity. Soil type also influences fumigation because it influences pore size distribution. An excess of fine particles or of organic matter also favours sorption which lowers the effective concentration of the fumigant. Tilth also affects the issue, for a "clotty" soil with many gross air spaces cannot retain vapour. Excess moisture decreases porosity, increases the amount of nematicide held in solution and causes thick water films slowing down the last stages of diffusion which lead to contact with the nematode to be killed (Fig. 1). In contrast, fumigation of a very dry soil leads to rapid gas escape, increased sorption on to clay particles and inactivity of the nematicide. For highly volatile nematicides such as bromomethane an impervious surface seal is essential in the form of gas tight sheeting. Dichloropropene, trichloronitromethane, and methylisothiocyanate would also perform better if the surface were sealed by polythene, impervious paper or heavy watering (1,000 galls/acre = 1.1 cm.), operations economic with seedbeds or expensive crops but, agriculturally, only heavy rolling is economic and is always beneficial even though not fully effective. Quite apart from the physical aspects of fumigation, micro-organisms or other components of the soil may hasten breakdown. Where nematicide precursors such as the dithiocarbamates, (Table 2.) mercury compounds or halogen liberators are used, breakdown is an essential part of the operation.

There are many difficulties in attempting to measure the nematicidal activity of chemicals in the laboratory and in assessing their performance in the field. The field dosages given in Table 1. in no way reflect the activity of the compounds listed because of the confounding effect of the many variables already discussed. Assessing mortality is almost always much more laborious and time consuming than for insects or fungi. In streamlined screening tests these difficulties tend to be glossed over. It is often hard to decide when a nematode is dead. Dead larvae within eggs cannot be distinguished from living until gross changes have had time to occur. Discriminative staining has not proved reliable with eggs, larvae or adults and, although it is a simple matter to separate active from

passive larvae and adults by suitable filters, inactivity does not always indicate death. These difficulties are greatest for cyst-forming nematodes, the closely related root-knot nematodes and for those forms which invade roots. The problem for cyst forming nematodes is analysed in Table 4. Root-knot nematodes are often used for screening and kill is estimated by counts of primary galls formed on indicator plants. As with cyst-nematodes, delayed hatch might delay invasion so giving an over-estimate of kill; larvae that invade may be unable to develop completely and counts of galls formed by these would under-estimate the kill. Effects of this kind may not greatly upset a screening programme but are important in research where more precise estimates of toxicity are required. The difficulties outlined have been emphasised by the work of Hague and his colleagues at Imperial College Field Station. Working mainly with potato root eelworm (Heterodera rostochiensis), they have plotted probits of kill against dosage and obtain the median lethal doses for bromomethane, dibromoethane and dibromochloropropane. For this work they have found the final cyst count the most reliable criterion.

Dosage of nematodes by exposure to varying concentrations of a toxicant for a standard time or a standard concentration for varying times brings in the concept of concentration-time-product (C. T. P.). Over middle ranges of concentration and time the C. T. P. is usually regarded as a constant if measured under similar conditions. Recent work on free living and migratory soil nematodes using methyl bromide has shown that the C. T. P. law breaks down (Table 5.). Very low concentrations of chemical give extremely high kills with long exposure time (Hague in litt). The lower field dosages of dibromochloropropane required compared with bromomethane or dibromoethane (Table 1) may reflect greater persistence arising from low volatility rather than greater inherent toxicity. The advantages of low volatility, if real, cannot be pushed too far or the self dispersing properties of the compound are lost. Greater quantities may then be necessary to achieve the desired kill or recourse must be had to special methods of cultivation to ensure thorough mixing with the soil as with mercury compounds.

In field trials, yield is often no criterion of kill because other effects are confounded with it. The final cyst population too is available only after harvest and long after application of treatments. Unrelated events might well influence cyst production in the interim. For this reason my colleague Dr. Peachey has attempted to use root invasion as a criterion because it can be obtained much sooner after treatment, either using root samples taken from the field plots or pot plants grown in representative soil samples under standardised conditions. Although density of larvae/g root is not directly related to the final kill and there are difficulties in deciding just when the samples should be taken, this criterion is useful in that it enables more plots to be handled and tests to be repeated within the compass of a single season. It may also be argued that injury is related to invasion and that delay in invasion is part of the beneficial action of the nematicide.

So far I have spoken only of the problems associated with the use and

testing of general nematicides. These are broadly toxic to insects, fungi and plants. Sometimes their phytotoxic properties also help to suppress weeds. The grower accepts these useful side effects and the increased growth from nutrients released by so-called soil amendment, all of which help to make soil treatment more attractive. One problem which remains is the development of nematicides to free bulbs, tubers, corms, transplants and nursery stock from parasitic or adhering nematodes, for noxious species are often carried to new areas by this means and virgin land becomes infested when first planted. For this purpose more specialised nematicides are needed with high nematicidal power yet low toxicity to plants and to mammals.

Another problem is the exploration of ideas gained from a study of host-parasite inter-relationships and of toxic principles obtained from plants after the manner of nicotine, rotenone and pyrethrum.

Peacock, in a recent address to the Association of Applied Biologists, listed the ways in which systemic compounds moving down to the roots might give protection. They might be toxic to nematodes entering or feeding upon the roots as is α-terthienyl in the roots of Tagetes. They might inhibit some host response to invasion which neamtodes depend on for survival, as in the suppression of giant cell formation by maleic hydrazide, or inhibit the formation of the hatching factors as with maleic hydrazide, sodium fluoracetate, and fluoracetamide. Finally they might diffuse out from the roots and exert a toxic, repellent or anti-hatching effect in the rhizosphere.

The Tagetes nematicide was isolated in Holland by Uhlenbroek and Bijloo who have already tested some related thienyls. At least two other compounds in this class are known to be nematicidal (Table 6). Toxic principles also occur in Asparagus roots and possibly in Crotalaria. The former is an unidentified glycoside which is said to decrease Trichodorus populations in soil when applied as a drench or sprayed on to leaves. Tarjan injected toxic compounds into citrus trees affected by spreading decline in Florida without success, but Peacock found he could introduce into tomatoes by means of a woollen wick many substances that were translocated downwards and inhibited nematodes in the roots. When sprayed on the leaves, however, most did not penetrate or were too phytotoxic. The finding of compounds to fill the roles listed by Peacock will not be easy but there is always the chance that someone will succeed.

Once it was thought that characterisation of the hatching factor for potato root eelworm would lead to its synthesis and use in control. Work in the interim on hatching makes this seem unlikely. Hatching factors, although active at great dilution, are also highly unstable and quite unfit for application to soil. Here again, when characterised and substituted in various ways to increase persistence, something usable may perhaps arise.

In many countries nematode problems remain to be recognized, surveyed and assessed. As this is done more outlets will arise for nematicides. In the developed countries mechanisation is tending to force growers to concentrate on a few crops so that expensive machinery can

be used to the full and, consequently, traditional methods of control such as crop rotation are often difficult or inconvenient to apply. For these and other reasons the development of positive methods of chemical control at economic prices is an increasingly desirable pursuit.

Table 1

Properties and field dosages of some nematicides

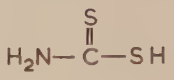
	BP °C	VP 20-25°C	% Water solubility	Minimum soil temperature for use °C	°F	Approximate field dosage range lb/acre
Bromomethane	5	1420	1.3	5	40	400-800
Carbon disulphide	46	357	0.3			1000?
1,3-dichloropropene	104-112	31	0.1	7	45	100-400
trichloronitromethane	112	24	0.2	10	50	400-800
methyl isothiocyanate	119	21	0.8			150-250*
1,2-dibromoethane	132	11	0.4	16	60	50-250
1,2-dibromo-3-chloropropane	196	<1	0.1	18	65	20-60
Trans1,4-dibromobutene-2	205	<1				75-100
Mercury	357	<0.01	→0			5**

* as methylisothiocyanate or derived from a dithiocarbamate precursor, claimed effective at low temperatures.

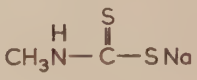
** as grey powder, mercuric oxide, calomel etc.

The formulae of some dithiocarbamates and related sulphur compounds precursors of nematicidal isothiocyanates.

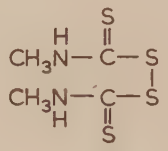
Dithiocarbamic acid



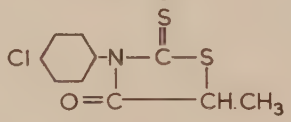
Sodium methyl dithiocarbamate



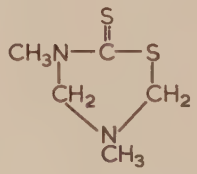
Dimethyl thiuram disulphide



Parachlorphenyl methyl rhodanine



Dimethyl tetrahydro thiadiazinethione



General formula

Probable nematicidal and fungicidal breakdown product; isothiocyanate

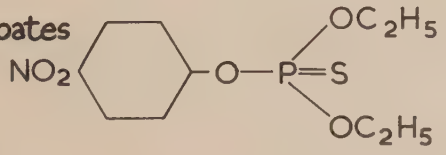
Methyl isothiocyanate

Characteristics.

Low volatility,
Water solubility varies with chemical configuration,
Phytotoxic, Irritant.

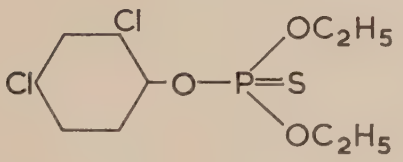
Some parathion like substances with nematicidal activity

Diethyl phosphorothioates
Nitrophenyl



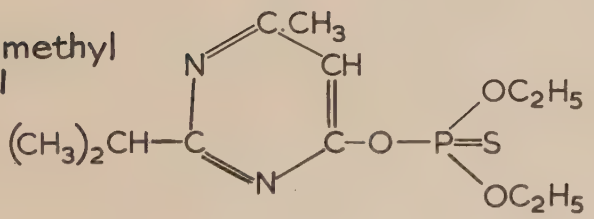
(1)

Dichlorophenyl



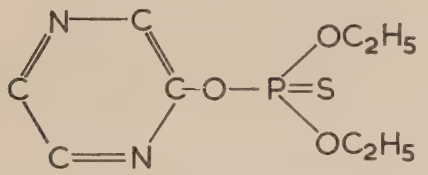
(2)

Isopropyl methyl
pyrimidyl



(3)

Pyrazinyl



(4)

Characteristics

Breakdown in soil to potent cholinesterase inhibitors.
All derivatives of diethylthiophosphoric acid.
High BP, Low VP, Low water solubility.
High mammalian toxicity (except 3).
Low phytotoxicity.

Table 4. The effects of nematicides in soil: cyst forming nematodes

Dosage of soil containing encysted eggs	Population after dosage			Invasion, development and reproduction on host plant after dosage		
	Immediate	Intermediate	Final	Root population*	Cyst population	Egg population
Immediate Kill	Dead eggs not obvious	Dead eggs more obvious	Dead eggs disintergrated	Some invading larvae may be incapable of development or reproduction.	Confounded with mortality in roots due to competition or other causes.	Confounded with mortality in roots during cyst development and with all those factors which influence ovulation and egg nourishment.
Final kill		Hatching may be delayed. Some moribund eggs may hatch.	Mortality complete but may include that from other sources and may be confused with spontaneous hatch.	Larvae/g root not directly related to survival; number successful in invading varies with soil conditions.	New cysts formed represent the number of female invasions that successfully complete development under the conditions of the trial.	Final egg populations affected by many factors besides nematicidal treatment and separated in time by months.
Availability of results	Shortly after dosage	Some time after dosage	Only after considerable delay	Results available shortly after planting	Results available only after completion of experiment	
	For hatching tests in addition to egg estimates, add 5 weeks.					

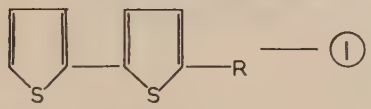
* Estimates can be obtained from root, from samples, separately from plants grown in representative soil samples under standardised conditions, or from extracted cysts added to pots of sterilised soil.

Table 5. The inconstancy of the time-concentration product at extremes of time and concentration. Methyl bromide used against migratory and free living nematodes

Hours Exposure	Concentration mg.	CTP	% Mortality
1	100	100	0
10	10	100	50
100	1	100	100

Table 6 Some thienyl and similar compounds with nematicidal properties.

Experimental stage only



— ①

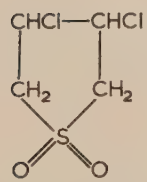
Where R =

Derivatives of dithienyl.

CH_3
Cl
NO_2
COC_2H_5

— ②

Tetrachlorothiophene.



— ③

Dichlorotetrahydrothiophene–dioxide.

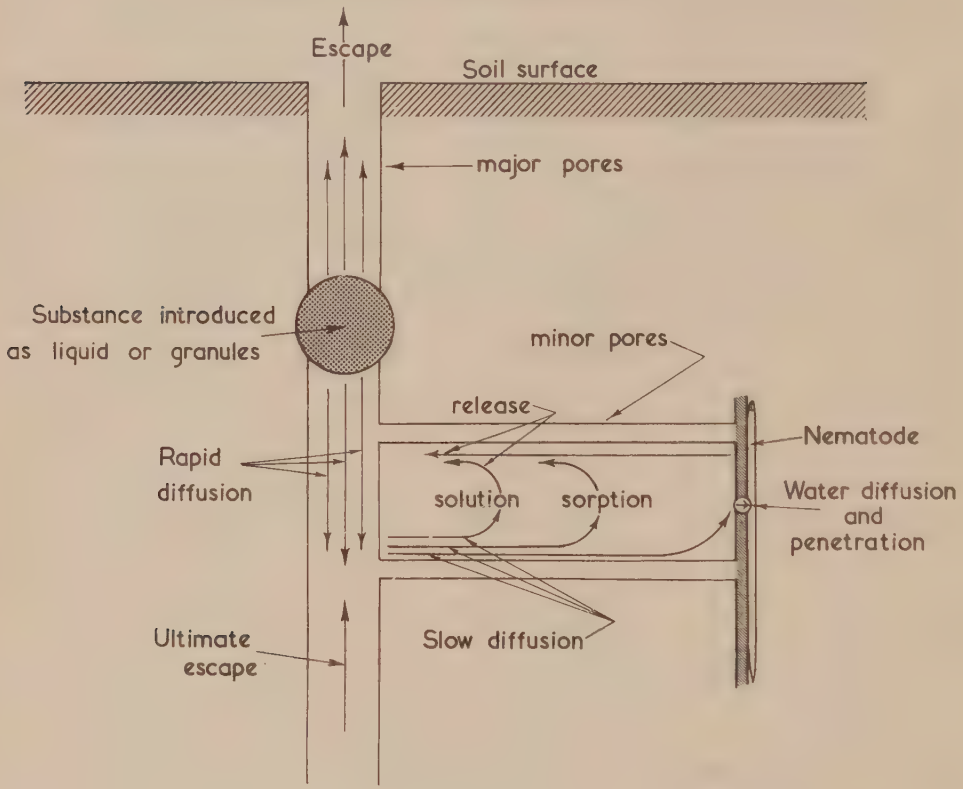
Characteristics

Low volatility. Low water solubility.

③ somewhat phytotoxic.

② & ③ dosages suggested 20–60 lb./acre.

Diagrammatic representation of the processes concerned in soil fumigation.



FIELD EXPERIMENTS WITH A NEW ORGANO-PHOSPHORUS NEMATOCIDE AGAINST POTATO ROOT EELWORM

by W. D. Fraser (Field Station, Wisbech) and C. D. Lindley
(Cyanamid of Great Britain Limited)

Summary

Work is described with E. N. 18,133, a new organo-phosphorus nematocide, applied as a granular formulation for the control of potato root eelworm (Heterodera rostochiensis).

When applied immediately before planting to land infested with potato root eelworm, it significantly increased the yield of ware potatoes by amounts ranging from 15% to 60% in field experiments carried out over three seasons. It was more effective as a band application in the furrow than when broadcast and admixed by rotovation.

Lower rates of use were required on silty loam soils than on peat fen soils to give similar increases of yield. Furrow application on silt soils of 2 lb a. i. per acre was as effective as 4 lb, whereas on peat soils 6 lb was more effective than 3 lb.

It caused a decrease of yield in two experiments on eelworm-free soil.

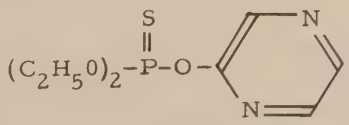
E. N. 18133 reduced the number of aphids on the leaves during the season by systemic action.

No detectable residues of E. N. 18,133 (< 0.02 p. p. m.) were found in the tubers in August or at harvest following furrow application of 8 or 12 lb.

Introduction

Experimental Nematocide 18,133 (E. N. 18,133) OO-diethyl O-2 pyrazinyl phosphorothioate was discovered at Cyanamid's Stamford Laboratories in 1956.

The structural formula is:-



It is a liquid with a solubility in water of 0.1%.

Preliminary trials in the United States showed it to be active against several species of free living plant parasitic nematode. Trials were begun in the United Kingdom in 1959 against potato root eelworm (Heterodera rostochiensis).

Materials and Methods

In 1959 and 1960 attapulgite granules containing 5% E.N. 18,133 were used in the trials and in 1961 the formulation consisted of 10% E.N. 18,133 on attapulgite granules (30-60 mesh).

In 1959 a randomized block design with 4 replicates was used, the plot size being 5 rows 15' long. The layout in 1960 and 1961 consisted of 5 x 5 Latin squares. The plot size in 1960 was 5 rows x $16\frac{1}{2}$', and in 1961, 3 rows x 15' with an untreated guard row between plots.

Two experiments were carried out in 1961 on clean soil to test the effect of the chemical in the absence of eelworm. One was a split plot trial with the varieties Majestic and King Edward as the main treatments and rates of application of E.N. 18,133 as the sub-treatments. The other was a randomized block with four-fold replication. The plot size was 5 rows x 15' in both trials.

Broadcast applications of E.N. 18,133 granules were made after preparation of the land and the chemical was incorporated into the soil by rotovating or harrowing. Ridging and planting of the seed took place on the same day. Furrow applications of granules were made immediately before planting. The tubers were planted 18" apart in the rows.

Soil samples were taken for eelworm counts before laying down the trial and again after harvesting. Twenty soil cores 6 to 8" deep were taken with a $1\frac{1}{4}$" auger from each plot and the samples bulked.

After drying and thorough mixing, 100g of soil was washed through a Fenwick can. The cysts were extracted from the residue by filtration and counted. In 1960 to assess viability 50 cysts were withdrawn at random from each sample and placed singly in a small drop of water on a glass slide. Each cyst was squashed with a glass rod and assessed for viability of eggs and larvae. Cysts containing 50 or more full eggs and larvae were classified as full, and under 50 as half-full. It was felt that a more accurate classification could be achieved by precise counts of eggs and larvae and this procedure was used in 1961. Again 50 cysts were taken at random from each sample and moistened and squashed with a glass rod. The squashed sample was washed into a boiling tube and made up to 30 ml with water. The suspension was agitated with an electric stirrer for 10 seconds to separate the eggs from the shells of the cysts. To obtain a uniform distribution of eggs and larvae air was bubbled into the suspension for a few seconds and 1 ml samples withdrawn and examined in a Fenwick counting slide. Counts were made of the total number of eggs and larvae, and they have been expressed together as eggs per gram of dried soil.

All results have been statistically analysed. An asterisk (*) signifies that the difference from the control is statistically significant at $P < 0.05$, and two asterisks (**) at $P < 0.01$.

Results

1959 Trial:

This experiment was carried out on a light silt site near Holbeach, Lincs. The previous crop of early potatoes in 1956 had been severely attacked by eelworm. The plots were treated with E.N. 18, 133 and planted with Majestic seed on 12th May. The results are shown in Table 1.

Table 1. Effect of E.N. 18, 133 Granules on Shoot Emergence, Yield of Potatoes and Eelworm counts at Holbeach Site, 1959

Treatment (lb a.i./acre)	No. shoots as % of control	Yield of Ware potatoes as % of control	No. of eggs/g dried soil	
			Pretreatment	Postcropping
1 lb Furrow	93.6	98.1	76	193
2 lb "	89.8	121.9	96	232
4 lb "	93.8	129.8	82	129
8 lb "	81.2	98.9	78	169
16 lb "	80.8	85.3	61	146
Control	100.0	100.0	90	252
Control yield (Tons/Acre)		4.1 tons		

All rates of E.N. 18, 133 caused a non-significant reduction in the number of shoots as shown by counts on 30th June. The 2 and 4 lb rates increased the yield of ware potatoes, but 16 lb caused a decrease indicating phytotoxicity. The low yields were probably partially due to the late planting date and the drought conditions of 1959.

The eelworm count as eggs per g of soil was higher after cropping than before treatment in all treatments. However, the increase with the 4, 8 and 16 lb treatments was not as great as with the others.

Counts of aphids on the leaves in July showed that E.N. 18, 133 at 4, 8 and 16 lb had given a statistically significant ($P < 0.01$) reduction over the untreated.

1960 Trials:

In the light of the preliminary findings with E.N. 18, 133, three experiments were laid down comparing two methods of application on two soil types. Details of the trials are given in Table 2 and results in Table 3.

Table 2. Details of 1960 Experiments

Site Number	2	3
Location:	Sutterton, Lincs.	Holme, Hunts.
Soil type:	Silty Loam	Peat Fen
Date of treatment and planting:	11th April	8th April
Variety of potato:	Majestic	Majestic
Row width:	28 ins.	30 ins.
Method of mixing broadcast treatments:	Harrowing	Rotovating
Date of emergence count:	15th June	8th June

Table 3. Effect of E.N. 18, 133 Granules on Plant Emergence and Yield of Potatoes

Treatment (lb a.i./acre)	No. plants as % of control		Yield ware potatoes as % of control	
	Site 2	Site 3	Site 2	Site 3
4 lb Furrow	101.9	102.0	133.1	126.4**
4 lb Broadcast	101.9	108.2	129.8	115.4*
8 lb "	100.0	106.1	145.8*	118.8*
16 lb "	100.0	106.1	136.6	135.7**
Control	100.0	100.0	100.0	100.0
Control yield (Tons/acre)			6.3	7.5

Counts of the number of plants at both sites showed that E.N. 18, 133 did not affect germination.

E.N. 18, 133 gave marked increases of yield over the untreated. The greatest increase at Site 2 was with 8 lb broadcast and at Site 3 with 16 lb broadcast, but 4 lb furrow increased the yield at both sites by 2 tons per acre. At Site 2, 16 lb broadcast gave a lower yield than the 8 lb rate, indicating some degree of phytotoxicity.

These results suggested that the peat fen soil required a higher rate of application than silt soils for a comparable effect on yield.

Table 4. Effect of E.N. 18,133 Granules on Eelworm Cyst Counts

Treatment (lb a.i./acre)	No. of full cysts per 100 gm. dried soil			
	Site 2		Site 3	
	Pretreatment	Postcropping	Pretreatment	Postcropping
4 lb Furrow	11.6	22.6	56.2	84.6
4 lb Broadcast	8.4	30.2	40.6	107.8
8 lb "	13.8	26.4	53.0	120.8
16 lb "	13.0	37.4	47.2	45.4**
Control	10.2	26.2	61.8	115.2

The eelworm counts expressed as full cysts per 100 g. of soil were higher after cropping than before treatment at both sites, with the exception of the 16 lb broadcast treatment at Site 3.

No detectable residues (< 0.02 p.p.m.) of E.N. 18,133 were found by the Laws and Webley (1961) method in tubers taken from the highest rates of treatment at harvest.

1961 Trials:

Further experiments were laid down in 1961. These included two trials to determine the influence of E.N. 18,133 on potatoes in the absence of eelworm and ten trials on infested areas. The rates of E.N. 18,133 were 50% higher on the peat fen sites than on the silt sites.

a) Trials on eelworm-free soil:

Table 5. Details of 1961 Experiments

Site Number	4	5
Soil type:	Silt	Peat
Location:	Wisbech, Cambs.	Methwold Hythe, Norfolk
Date of treatment & planting:	11th April	13th April
Variety:	Majestic & King Edward	Majestic
Fertiliser:	10 cwt/acre 10-10-18	4 cwt/acre K_2O 3 cwt/acre Triple Supers
Row width:	28 "	28"
Date of emergence count:	23rd May	- -
Previous potato crop:	1953	Pre 1941

The absence of eelworm at Site 4 was established by the examination of soil samples. Site 5 had been a grass field for twenty years.

The number of shoots from 10 plants were counted at Site 4 on 23rd May and the mean values, expressed as a percentage of the control, are shown below in Table 6.

Table 6. Effect of E.N.18,133 Granules on Shoot Production of Majestic and King Edward potatoes

Treatment (lb a.i./acre)	No. of shoots as % of control
2 lb Furrow	100.7
4 lb "	93.2
8 lb "	85.4
4 lb Broadcast	89.9
8 lb "	96.3
Control	100.0

There was an indication that the treatments reduced the number of shoots and this effect was most marked at the 8 lb furrow level. Visual assessment scores also indicated a small reduction in vigour associated with the plant in the 8 lb furrow treatment, and both observations suggested that this rate was mildly phytotoxic. As the season progressed the differences disappeared and in the late stages of growth it was impossible to distinguish one treatment from the other.

The effect of the chemical on yield is shown in Table 7 for both sites.

Table 7. Effect of E.N.18,133 Granules on Yield of Ware Potatoes on Eelworm Free Soils

Treatment (lb a.i./acre)	Yield of ware potatoes as % of control		Treatment (lb a.i./acre)
Site 4	Site 4	Site 5	Site 5
2 lb Furrow	89.4	105.2	3 lb Furrow
4 lb "	84.1*	92.1	6 lb "
8 lb "	85.6*	95.8	12 lb "
4 lb Broadcast	91.3		
8 lb "	96.7		
Control	100.0	100.0	Control
Control yield (Tons/acre)	20.8	16.5	

On the silt soil the treatments were associated with lower yields and the reductions were greater from furrow applications than from broadcasting. The yield differences between 4 or 8 lb furrow and the control were statistically significant. Slight yield reductions occurred with the high rates on the fen soil but they were not as marked as on the silt soil.

The results suggest that the rates tended to depress yield and in view of this the observed yield response in previous trials may be attributed to the nematocidal property of E.N. 18,133 and not to any side effects from the chemical.

b) Trials on eelworm-infested soil

Details of the sites are tabulated below.

Table 8. Details of 1961 Experiments

(i) Peat Fen Soil

Site Number	6	7	8	9	10
Location:	Thorney, Cambs	Holme, Hunts	Farcet, Hunts	Methwold, Hythe, Norfolk	Methwold, Hythe, Norfolk
Date of treatment & planting:	24th April	18th April	29th March	13th April	14th April
Variety:	King Edward	Majestic	Majestic	King Edward	Record
Fertiliser:	10 cwt/acre 12-12-18	12 cwt/acre 6-15-15	10 cwt/acre 8-10-8	4 cwt/acre K_2O 3 cwt/acre triple supers	1 cwt/acre sulph. of ammonium 3 cwt/acre triple supers
Row width:	28"	30"	28"	28"	30"
Date of emergence count:	6th June	- -	- -	1st June	- -
Previous potato crop:	1957	1952	1955	1957	1957
Mean pre-treatment count (egg/gm):	55.3	42.5	149.3	106.5	25.8
N.A.A.S. category of P.R.E. infestation:	Fairly high	Fairly high	High	High	Moderate

Table 8. Details of 1961 Experiments (Cont'd)

(ii) Silt Soil

Site Number	11	12	13	14	15
Location:	Fosdyke, Lincs	Swineshead, Lincs	Christchurch, Cambs	Christchurch, Cambs	Kings Lynn, Norfolk
Date of treatment & planting:	16th March	28th March	17th March	24th March	12th April
Variety:	Majestic	Majestic	Majestic	King Edward	Majestic
Fertiliser:	10 cwt/acre 8-10-8	10 cwt/acre 8-10-8	10 cwt/acre 8-10-8	12 cwt/acre 10-10-18	10 cwt/acre 8-10-8
Row width:	28"	28"	28"	28"	28"
Date of emergence count:	10th May	- -	- -	24th May	- -
Previous potato crop:	1957	1956	1960 (Earlies)	1960	1959
Mean pre-treatment count (egg/gm):	68.7	74.8	40.8	76.6	7.3
N.A.A.S. category of P.R.E. infestation:	Fairly high	Fairly high	Fairly high	Fairly high	Low

To assess the influence of E N.18,133 on emergence, counts of the number of shoots per plot were made at Sites 6, 9, 11 and 14. Analysis of the results showed that none of the rates tested affected the number of emerged shoots.

The results from the peat soils are given in Table 9.

Table 9. Effect of E.N.18,133 Granules on Yield of Ware Potatoes on Peat Soils

Treatment (lb a.i./acre)	Yield of ware potatoes as % of control					
	Site 6	Site 7	Site 8	Site 9	Site 10	Weighted Mean
3 lb Furrow	108.5	101.0	141.8	98.6	111.8	104.9
6 lb "	120.8	104.7	158.2	101.2	118.5**	109.7**
6 lb Broadcast	102.3	103.2	114.3	79.6	112.9*	103.8
12 lb "	105.5	113.8**	123.9	103.1	121.3**	115.0**
Control	100.0	100.0	100.0	100.0	100.0	100.0
Control yield (Tons/Acre)	3.6	8.5	3.1	8.5	7.3	

The nematocide exerted a response at all sites with the exception of site 9, and at sites 7 and 10 the increases were statistically significant at certain levels. The higher rates were an improvement over the lower rates for each method of application and this effect was consistently observed at all centres.

At site 8 there were apparently large responses, of the order of 50%, to furrow application, but the differences failed to reach significance. There was high variability here arising from frost damage. Severe frost in late May affected the growth of the plants at all sites and this probably is one cause of the low yields.

The use of the weighted mean instead of an arithmetic mean has been made because of the varying accuracy of the five experiments, after statistical tests had shown that the treatment effect did not differ from experiment to experiment. The means weight the more accurate experiments proportionately higher and they are largely determined from Experiments 7 and 10.

Analysis has shown that over all five experiments 6 lb furrow and 12 lb broadcast treatments have given statistically significant increases of 9.7% and 15.0% respectively.

Attempts have been made to find a relationship between eelworm population and yield increases but there was no consistent trend and responses of equal size were obtained at centres with "moderate" and "severe" categories of infestation.

The results from the silt soils are summarized in Table 10.

Table 10. Effect of E.N.18,133 Granules on Yield of Ware Potatoes on Silt Soils

Treatment (lb a.i./acre)	Yield of ware potatoes as % of control			
	Site 11	Site 12	Site 13	Mean
2 lb Furrow	99.6	155.1**	159.3	138.0
4 lb "	113.5	150.3**	153.4	139.1
4 lb Broadcast	93.9	130.6**	144.2	122.9
8 lb "	98.5	118.0*	148.8	121.8
Control	100.0	100.0	100.0	100.0
Control yield (Tons/acre)	7.5	5.0	4.2 (Estimated)	

Analysis has shown that the treatment effect varies significantly from experiment to experiment and therefore the use of a weighted mean cannot be made. Experiment 12 was considerably more accurate than either 11 or 13.

At site 11 the only observed response was derived from 4 lb furrow and this was not statistically significant. There is no explanation for the general lack of response here since the plots were classified in the "fairly heavy" category of infestation. The results from site 12 are in sharp contrast to those from site 11 and all rates showed significant increases over the control. Furrow application was superior to broadcasting and the mean difference was represented by a 24% increase in yield.

The viability of the tubers planted at site 13 was low and only 49% to 67% of the tubers planted survived to produce mature plants. In an attempt to equate the plant numbers for yield estimates it has been assumed that yield was a function of the number of tubers. On this basis the yield responses obtained are of the same order as at site 12.

Increases of yield of the order of 300% were obtained with E.N. 18, 133 at site 14 but the control yielded only 5 cwt of ware potatoes per acre. Symptoms of severe eelworm attack were evident on all treatments in July.

Aphid counts on the leaves were made at sites 4, 5 and 11 at intervals during June and July. E.N 18, 133 was relatively ineffective on the peat fen site (No. 5), but it gave a significant reduction of aphids with 4 and 8 lb furrow treatments on the silt sites in mid-June. Differences were less marked in early July except at 8 lb furrow.

Residues of the order of 0.1 p.p.m. were found in the tubers in mid-July. No detectable residues (< 0.02 p.p.m.) were found in mid-August samples.

Discussion

The results with E.N. 18, 133 in field trials in East Anglia over three seasons have shown that the yield of ware potatoes has been increased by amounts ranging from 15% to 60%. That these increases have been derived directly from the nematocidal effect of E N. 18, 133 has been substantiated by two trials in eelworm-free soil where the nematocide tended to depress yields.

The extent of yield response has varied with soil type, dosage and method of application. The chemical was generally more efficient on silt soils than on peat fens, though a high application rate in 1960 on fen soil gave a substantial yield increase and the eelworm population remained at the same level as observed before cropping.

On both soil types the application of the nematocide to the furrow was superior to broadcasting. On the fen soils, a furrow application of 6 lb per acre was more effective than 3 lb. The same difference was not observed on the silt soils, 2 lb giving the same response as 4 lb.

In 1961 efforts were made to select sites with a varying population of eelworm to represent the N.A.A.S. "low" to "severe" categories of infestation. Of the ten sites, 1 was "low", 1 "moderate", 6 "fairly high" and 2 "high". The results from the "low" site are not yet available. It will be seen that the majority of trials have been carried out on "fairly high" categories showing that the nematocide has been exposed to a rather thorough test of its properties.

Insufficient data is available at present to demonstrate the effect of E.N.18,133 treatment on the eelworm population. This will be reported at a later date after examination of the samples from each site used in 1961. The 1959 and 1960 trials indicated that the post cropping populations had increased with E.N.18,133 but that this increase was not as great as that in the untreated controls.

The yields of potatoes in the 1961 trials were comparatively low in certain instances. This was caused by a number of factors other than the effect of the nematodes. For example, at two sites there was a low percentage emergence of tubers and severe frosts in late May caused extensive damage on most of the peat fen sites. A planting distance of 18 inches in the row, regardless of seed size, was used in the majority of the trials, resulting in a low weight of seed per acre being set.

The yields from the two eelworm-free sites were very high, and more than double the best of the trials on infested soil. Neither of these sites had grown potatoes for many year, and in both cases large seed was planted. No frost damage occurred.

During 1960 a pot test was carried out to supplement the field experiments, in which potatoes were grown in John Innes compost inoculated with cysts of potato root eelworm. The best control of eelworm was given by thorough mixing of the nematocide with the soil, and was superior to the control given by placing E N.18,133 under the tuber at planting. This suggests that the reason for the broadcast treatments of E N.18,133 in the field being inferior to the furrow treatments was the inadequate mixing of nematocide in the soil. This conclusion is supported by the work of Staniland (1961) with fluorescent tracing materials which has shown that rotovating a dust broadcast on the surface gives an uneven mix in the top six inches of soil.

The furrow treatment has the advantage of ease of application over the broadcasting and machines will shortly be available commercially to apply granular insecticides to potatoes at planting time.

It has been shown in the field that E.N.18,133 possesses systemic aphicidal properties but it is not clear if there is any systemic nematocidal action. Experiments are in progress to determine the mod of action and this knowledge will considerably help in devising methods of application in the field.

Further work is required to evaluate the effect of E.N.18,133 on potatoes in soils containing "low" to "moderate" infestations of eelworm (i.e. under 39 eggs/g) in the different regions of the United Kingdom where this disease constitutes a problem.

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The co-operation of many farmers, too numerous to mention by name, who provided the experimental sites is also gratefully acknowledged.

DETAILS OF DISCUSSION

SESSION I. THE EELWORM PROBLEM

Q. Mr. P. de Pietri-Tonelli.

What is the pH of the soils where the experiments have been carried out?

A. Mr. C.D. Lindley

Roughly neutral, if anything, on the alkaline side.

Mr. J.E. Peachey stated:

I would like to make the point that because we are using several poisons as nematicides it does not make impossible the study of subtle effects of kill. It is known that methylisothiocyanate has a pickling effect on eggs in treated cysts. Dichloropropene shrivels Xiphinema sp. in a different way from methyl isothiocyanate and dibromochloropropene appears to immobilise populations before kill takes place. Physiological studies following up these differences may lead to further advances.

Q. Mr. P. Everest-Todd

Have Messrs. Lindley and Fraser considered the value of soil incorporation of the organo-phosphorus compound by a machine such as the unit developed by Dr. J. Grainger?

A technique such as Grainger's would reduce the initial crop set-back and therefore enhance the yield response.

A. Mr. C. D. Lindley

I think it well might. We have given some thought to this use of the machine. Our thoughts are that it is a fairly costly machine, it is a fairly difficult machine to operate. It is necessary, I think, to keep the method of treatment as simple as possible and that is why we have been so interested in the possibility of putting material in the furrow. The other thing is to keep the rate of application down as low as possible and the results show that with broadcast application the rate would have to be probably in the region of 8 lb active per acre, whereas with furrow application a rate somewhere around 2 or 4 would appear to be sufficient. What we really need to do is to get local mixing in a band in the furrow and see whether it is possible to do this. It is something we are going to look at.

Q. Mr. T. E T. Trought

Would the mammalian toxicity of E.N. 18,133 affect its use in agriculture?

A. Mr. C. D. Lindley

It looks pretty horrible 12 mg/kg acute oral toxicity. As I explained, we have been using granular formulations and it is known that granular formulations of toxic compounds are very much safer to handle because the risk of dermal absorption is reduced. If there is a need for this type of chemical I think operators would be prepared to wear a small amount of protective clothing to apply it.

INSECTICIDES, FUNGICIDES AND THE SOIL

A review of a symposium held on 28th February 1961 to discuss the effects of chemicals on soil-inhabiting organisms and other aspects of such treatments

By Hubert Martin

The ecological complexities of the soil flora and fauna are a sufficient excuse for our comparative ignorance of the consequences of any modification of the soil, whether by cultivation or, in the present case, the application of pesticides. Rarely has research on this subject got beyond descriptional stages and the interpretation of the results has given rise more to polemics than to further experiment. Consider, for example, the decades of discussion on reasons for the beneficial effects of partial sterilisation on crop growth, or the controversies over the role of antibiotics in soil ecology. Each new addition to the list of chemicals applied as pesticides to soil brings its problems, some specific to the chemical but most involving the whole ecological complex. Hence why ABMAC organised, on February 28th, 1961, a symposium to which some forty-five workers in the subject were invited.

The morning session was devoted mainly to the uses and consequences of the use of chlorinated hydrocarbons against root pests, in particular, root fly control. Dieldrin, for instance, is nowadays widely used for carrot fly control; H. C. Gough estimated that over half of the larger carrot growers followed the practice. Another extensive use is on potato and surveys by the Potato Marketing Board in association with the Plant Pathology Laboratory have revealed that, in 1957, about a quarter of the potato acreage is aldrin-treated for the control of wireworm. Apparently there is needless concern for the surveys found that wireworm infestation is significant on only about 5 per cent of the potato acreage.

Intensive work on the fate and action of aldrin, dieldrin and lindane in soils has been carried out, since 1955, at the National Vegetable Research Station. D. W. Wright, of that Station, reviewed the results on the persistence of these chemicals in fen and mineral soils. Persistence was assessed by the degree of carrot fly control obtained in the years following the incorporation of the insecticide by rotovation of the top four inches of soil; the plots were ploughed to eight-inch depth in succeeding years. Lindane, applied at $\frac{3}{4}$ lb/acre to medium loam soil at Wellesbourne, gave a partial control in the second and third year but none in the fourth year after application, though, at 2 lb/acre, a partial control was obtained in the fifth year. In fen soil at Mepal, Isle of Ely, the 2 lb/acre application gave partial control in the second year but none in the third year after application, though at 4 lb/acre effects persisted for four years. Aldrin and dieldrin persisted in the soil for much longer for the 4 lb/acre aldrin application gave complete control for six years in the Wellesbourne soil. In the fen soil, aldrin at 2 lb/acre gave no control in the third year but the higher rate of 4 lb/acre persisted for over five years and partial control

was shown in the fifth year. Dieldrin has a similar persistence for, at Wellesbourne, complete control was still obtained in the fifth year following application at 2 lb/acre and, at Mepal, a high level of control was obtained five years after a like application.

G. A. Wheatley, of Wellesbourne, has examined the persistence of these insecticides, used for the control of lettuce root aphid, by a bioassay technique using Drosophila melanogaster as test subject. A sandy loam soil treated with 1, 2 and 3 lb/acre was estimated to have retained 0.48, 1.1 and 1.9 lb/acre respectively after four years - about two-thirds in the case of the 3 lb/acre application. Similarly, a block of soil treated, in April 1956, with 2 and 4 lb/acre dieldrin apparently retained 1.4 and 2.3 lb/acre respectively in January 1960.

The results obtained at Wellesbourne confirmed the conclusions of American work that soil residues of these insecticides tend to an exponential decay and Wheatley gave estimates of their half-life based on the Wellesbourne work. That of dieldrin in black fen soil is 5 - 7 years, and, in sandy loam, 3.5 - 4.5 years. In the latter soil, both aldrin and heptachlor have half-lives of 3 - 4 years, endrin 2. - 2.5 years. On the basis of carrot fly control, the half-life of lindane in sandy loam is 2 - 3 years whereas that of DDT, based on analyses by Dr. J. T. Martin of the Wellesbourne soil, is 4 - 5 years. The apparent anamoly of the greater half-life of dieldrin in the fen soil and its lesser persistence as judged by carrot fly control is explainable if the insecticide is immobilised by adsorption or solution in soil lipids.

The practical implications of this work are at once apparent. The annual application of dieldrin at the rate of 1 lb/acre should lead to a maximum residue of 2.5 lb/acre over the years. Hence the amount of dieldrin applied for carrot fly control should be reduced on a sliding scale after the first year (see Plant Pathology, 1960, 9, 146). Wright estimated that the ideal half-life of a soil insecticide was about 100 days in the absence of any method of reducing the persistence of compounds of longer half-life. S. E. Jacobs was not hopeful of the selection of soil organisms able to metabolise these highly chlorinated compounds.

The use of bioassay techniques for the assessment of these insecticides in soil is indicative of the lack of suitable methods of residue analysis. This deficiency has, in part at least, been made good by the development of methods based on gas-liquid chromatography. J. G. Reynolds, of the Woodstock Agricultural Research Centre, described the technique employed for the detection and determination of the chlorinated hydrocarbons in soil. He discussed the advantages and limitations of the argon ionization and electron capture techniques. The latter is especially suitable for it has permitted the determination of amounts of aldrin and dieldrin less than 0.1 p.p.m. without the need for any time-consuming "clean-up" processes.

The wide use and high persistence of the chlorinated hydrocarbons has already created the experimental problem of finding suitable untreated areas for critical work on the responses of the soil flora and fauna to

insecticide treatment. The effects of aldrin and DDT treatments on soil fauna were reported on by C. A. Edwards and E. B. Dennis from plots treated with 3 cwt 1.25% aldrin dust or 2 cwt 5% DDT dust per acre. The soil organisms were extracted with a modified Salt and Hollick apparatus and an initial decrease in numbers was found with all groups examined, a result of cultivation from which recovery took about three months. Both insecticide treatments led to a fall in the number of Acarina. Collembola became scarce in the aldrin-treated soil but increased in number in the DDT-treated plots to a maximum nine months after treatment, after which numbers fell to a level slightly above that of the untreated plots. Dipterous and coleopterous larvae and pupae, thrips and symphilids were markedly suppressed by both treatments, root aphid numbers were sharply reduced by aldrin but not by DDT. Neither insecticide affected the numbers of parasitic nematodes, earthworms or enchytraeid worms.

These results are in general agreement with those of earlier work reported by J. G. Sheals, now of the British Museum. He had found a marked reduction of the saprophagous species by either DDT or BHC treatment and was concerned by the possibility of adverse effects on soil fertility which might result. He confirmed that DDT treatment caused an increase in collembola, though BHC had the opposite effect, and considered that this increase was due to a reduction of predatory species including mites.

T. H. Coaker spoke on the specific problem of the effects of predators on the survival of the cabbage root fly. The natural mortality of the fly at Wellesbourne was estimated to be as high as 95 per cent and about 60 per cent of this natural control was thought to be egg loss due to predatory beetles. Serological tests indicated that about fifteen species of beetle were responsible for the inverse correlation, observed over the three years of experiment, between egg survivors and beetle density. The application of insecticides at rates rather lower than required to control cabbage root fly has resulted in predator mortality to a degree which makes likely serious pest damage to brassica grown on land containing insecticide residues.

The long use of Bordeaux mixture for the control of apple scab in the Wisbech area provided F. Raw, of Rothamsted, with rich experimental material for the study of the effects of this practice on the earthworm population. In most other apple orchards this population is of the order of 2-3,000 lb fresh weight per acre; in two Wisbech orchards the only earthworms found were a few Lumbricus castaneus representing a population of only a few lb/acre. These orchards had received, over the period 1926-57, about 430 lb copper per acre, of which about 300 lb/acre had been applied since the orchards were grassed down in 1945-6. Analysis revealed about 2,000 p.p.m. copper in the surface mat, about 200 p.p.m. in the top two inches of soil and, below that, about 30 p.p.m. copper. The leaf litter decomposes slowly and the soil profile had developed typical "mor" characteristics. This drastic change in earthworm population and soil properties had had no apparent effect on apple yield but no answer was possible to the question of the effect of copper buildup on infection by Gloeosporium.

The general problems arising through the use of soil nematicides were discussed by J.E Peachey of Rothamsted. He described the various ways of assessing nematode control and referred to the increase in yield which often follows treatment both in the absence of nematodes and when no effect on the nematode population was apparent. R.S. Pitcher, of East Malling, made special reference to the "replant" problem which arises through the frequent failure of stone fruit, in particular peaches, to thrive in soil previously planted to stone fruit, a failure not seen on soil previously bearing pip fruit. The deleterious effect was overcome by heat treatment or the use of nematicides such as DD mixture even in the absence of nematodes or other pathogens. That virus was not responsible had been shown by the normal growth of affected trees when transferred to normal soil. A likely explanation is that residues of the previous planting gave rise to substances inhibitory to the growth of the young replants.

Contrasts between the biological activities of the dithiocarbamates, metham-sodium and nabam, were brought out in the discussion of a contribution by D. Tyson of Pan Britannica Industries Ltd. Nabam is used mainly as a soil fungicide but its use is reported to increase eelworm attack; metham-sodium is used as a nematicide but virus infection is increased, sometimes doubled, in tomatoes grown in the treated soil. The following explanations were offered; nabam is a good general fungicide and may kill fungi predaceous on eelworms; metham-sodium is a more specific fungicide which may, by delaying the breakdown of plant residues, prolong exposure to the virus. On the other hand, nabam may so improve root growth that the chance of eelworm attack is increased. None of these explanations is satisfying, nor was any explanation forthcoming of the control of "docking" disease by DD mixture but the etiology of this disease is still unknown. The complexity of these problems was emphasised by W. H. Read, of the Glasshouse Crops Research Institute, where he had developed methods, both laboratory and field, for the estimation of methyl isothiocyanate, the effective nematicide and phytocide produced in soil from metham-sodium. The laboratory method is sensitive to as low as 0.02 p.p.m.

J. Grainger, of the West of Scotland Agricultural College, stressed the importance of intimate distribution in the effective use of a soil pesticide and gave an account of the appliances he had tested and the results he had obtained in the particular case of the use of yellow oxide of mercury for the control of potato root eelworm. He had found that successful control was dependent on the initial pest population which, if too high, defied success by a single application. In the case of his Auchincruive trials, the critical figure for potato root eelworm was 1.2 cysts per gram of soil; for club root, a population producing about 40 per cent disease on untreated soil. High populations can be reduced to treatable level by consecutive applications.

The thesis that the success of a soil pesticide is due indirectly to biological control was first developed by the late D. E. Bliss on the basis of his work on the control of Armillaria mellea by soil fumigation with carbon disulphide. He considered that the Armillaria was killed, not by

the fumigant, but by the action of the soil fungus Trichoderma viride which becomes dominant in the treated soil. S.E.Garrett, of Cambridge, had re-examined Bliss's work and concluded that he had underestimated the fungicidal action of carbon disulphide. For instance, Garrett found that the dosage of fungicide needed to produce a dominance of T.viride in soil is four times that needed to kill A.mellea in small woody inocula. Nevertheless it is likely that T.viride can supplement the direct action of the fungicide and advantage may well be taken, in soil fumigation, of the high growth rate of this fungus which enables it to overtake in recolonization the more numerous surviving propagules of those fungi, chiefly Aspergilli and Penicillia, that have a higher degree of fumigant tolerance but are slower growers. He pointed out that proposals to combat soil pathogens by direct soil inoculation with antagonistic fungi were doomed to failure for the soil is a most selective habitat which must first be rendered suitable for the survival of the biological control agent. This contention was reinforced by E.Evans, of Chesterford Park Research Station, who outlined studies on the influence of formaldehyde on soil bacteria which he and his wife had made at Cambridge. T.viride again appeared as the most tolerant fungus and, among bacteria, species of Anthrobacter were the most resistant. Strains of both of these organisms were capable, in pure culture, of decomposing and perhaps utilizing formaldehyde. But in addition to the changed pattern of the soil flora brought about by formalin treatment, there was an improvement in nutritional status generally associated with an increased ammonia content. The Evans had found that this increase could be detected long before any increase in bacterial population, an observation which indicates that the phenomenon is of chemical rather than biological origin.

S.E.Jacobs, of the Imperial College, spoke briefly of the remarkable ability of bacteria to break down a wide range of exotic chemicals added, in small amount, to soil. Unfortunately, as had been emphasized earlier in the symposium, many soil pesticides were highly chlorinated and defy bacterial decomposition. The paradox that bacteria can attack compounds in the soil which would kill them in vitro is perhaps explained by the sorption of the toxicant by soil particles; generally speaking basic compounds were more strongly absorbed than neutral or acidic compounds. Some of his results gave support to the suggestion that, although killed, organisms can release enzymes capable of catalyzing the breakdown of certain compounds.

In answer to a specific request, C.Potter, of Rothamsted, gave an account of the changes in flavour produced in potatoes by soil treatment with chlorinated hydrocarbons. This work, sponsored by the Agricultural Improvement Council, was carried out at the Gleadthorpe, High Mowthorpe and Rosemaund Experimental Husbandry Farms and organoleptic tests were carried out under the direction of J.M.Harries of M.A.F.F. The insecticides were applied in the first year and their effects examined in that and the two following years. The rotations used were potatoes in all three years, cereals in the first year followed twice by potatoes, cereals for the first two years and then potatoes. The soils were a light sand, a

calcereous loam and a heavy clay. Aldrin, at 4 lb/acre, gave no change in flavour in any test; dieldrin, at 4 lb/acre, produced a slight, not unpleasant, change in the crop from the light sand; lindane, at $\frac{3}{4}$ and $1\frac{1}{2}$ lb/acre, produced unpleasant flavours under nearly all conditions.

FUNGICIDE SEED DRESSINGS

by Mary J. M. Noble,

Department of Agriculture and Fisheries for Scotland

In speaking of the control of soil-borne diseases of agricultural crops by the use of seed dressings, I would like to begin by attempting some definitions. First of all I have often protested against the use of the word 'dressings' in circumstances where 'treatment' is the more appropriate one but this time I have to speak about 'dressings' so I shall try to keep myself to that subject as I understand it and would like to define it. Again, I think now that I may be defined as a Seed Pathologist, that is one who studies all diseases transmitted by seeds and all injuries and diseases of the seed itself. It appears therefore that what you are about to hear is a dissertation upon seed dressings by a Seed Pathologist but may I first discuss this question of dressings as against treatment. The term 'dressing' means different things to different people dealing with different crops in different parts of the country! When potatoes are dressed out of the clamp or pit the operation consists of grading for size and removing the damaged and diseased onces and there is usually no question at all of chemical treatment. In the new Seeds Regulations, in fact, the terms 'dressing' and 'treating' for seed potatoes are used quite separately. Similarly in Scotland the term 'granary dressed' can be applied to cereal seed which has been sized or graded, had impurities removed, sometimes been polished mechanically, sometimes even has had its colour changed chemically, but it may have had no treatment or chemical dressing applied to it and there is the point where I think my objection is valid. Treatment and dressing are used as if they were synonymous and seed described as "granary dressed" has been given a second dose in England with resulting danger of phytotoxicity not perhaps so much when straight mercury is used each time but when the combined insecticide fungicide treatments are involved. Yet another point is that treated seed arriving in Scotland from "abroad" has been re-treated before sowing because the farmer considered it has not been "dressed" sufficiently. At least we who are present here should understand when seed is being treated to disinfect it and when a chemical is applied to seed to protect it from soil-borne fungi, from insects and other organisms entering through damaged seed. I know it's sometimes difficult and perhaps impracticable always to use the words in these rather restricted senses but I think we should at least try, and in saying this I have in mind recent press releases on seed "dressings", whereas in the new Seeds Regulations the operative word is "treated". Perhaps you'll say this is all too pedantic but we Scots are pedantic and I was assured by a recent visitor from Canada that I would be quite "in step" over there!

Now to get down to my title then. Let's seek for some good example of soil-borne diseases controlled by seed dressings and discuss them. In our common cereals it is usually considered that seed dressing does control both soil and seed-borne organisms. In the last year or two, however, I

have come to doubt very much if many soil-borne fungus disease of our common cereals are controlled either by seed dressing or by treatment. I expect some of you are thinking now, "what about Fusarium Foot Rot"? A few years ago we in Scotland carried out a survey of the seed in samples passing in commercial trade circles. We tested them not only in the laboratory, but in the field to determine the exact cause of some of the diseases such as foot rot, leaf spot, etc. We were surprised to find a very high proportion of seed infected with Fusarium nivale, commonly known as the snow mould, and recognised in countries such as Finland and Sweden as a major cause of foot rotting in most of the cereals but scarcely recorded in Britain. We hadn't realised until then that this fungus was so common in seed and when we isolated from some brown foot rot plants in the field we again found F.nivale. Sometimes other species were present as well but the evidence indicated that in Scotland these are quite often secondary invaders which come along after F.nivale has caused the rot. One of these, F.culmorum, has been described by Chesters and Parkinson as a normal inhabitant of the soil around the roots of oat plants, only becoming active as the plants die off. However, Jamalainen in Finland has found that seed dressed with mercury and thiram is protected against F.nivale. What do we know of F.nivale as a soil-borne organism in the United Kingdom? I would suggest that, as a parasite of oats, wheat and barley, this fungus should be more closely studied in this country especially its relationship to soil-inhabiting Fusarium spp.

There is, however, one cereal now grown here which provides a good example of control of soil-borne disease by seed dressings. Maize is now grown extensively in England and there's some in Scotland. I've no personal experience of this crop but the exchange of views with my colleagues, especially in America, and a study of the literature, shows that of all the cereals the seed coat of maize can be most frequently cracked and broken. Now if this seed is sown without a protectant it will almost invariably fail but with a protectant such as thiram or captan, or a mixture, excellent control is obtained so that the cracked seed is just as good as seed with a complete testa. This does not seem to apply in the case of wheat and oats and barley. In these cereals the cracked seed coat seems to allow other fungi to penetrate before the protectant can really become effective but we've discussed often enough before the question of micro-cracking in wheat and in barley and I think we are all quite well aware of these literally hidden dangers.

Peas are now grown as an agricultural crop in both England and Scotland. There is still a bit of damping-off and here the use of protectant is definitely good practice. Thiram and spergon are both effective but now we have another factor coming in because thiram has proved also to control seed-borne Ascochyta disease; something which I for one had not suspected. Another very big problem, of course, in peas is the question of seed weakness. This may be a question of age, of harvesting damage or, as we have recently recognised, a condition called "hollow heart" which results in rather weakened seedlings. Now, if this rather weak seed is sown under ideal conditions it will do perfectly well but in Scotland

at least, and I understand in some of the eastern England areas such as Cambridge, the soil conditions in early spring at sowing time may be anything but ideal and here a protectant such as thiram gives very good results apart from its disinfecting action on the seed. Peas in the field are also attacked by Fusarium sp. from the soil as well as fungi such as Pythium, the frequent cause of "damping-off", and protective dressing certainly reduces this risk. There is, of course, another classic example of a soil-borne disease controlled by seed dressings, that is the white rot of onions caused by Sclerotium cepivorum where a paste applied to the seed goes into the soil, acts as a local sterilant and wards off the fungus but that's from the horticultural field so we'd better leave it aside and conclude that in fact there are not nearly so many good examples of the control of soil-borne fungus diseases by seed dressings as you might think!

These observations I have so far made apply equally to the liquids and the dusts in the mercurial range. I understand from my chemical friends, of course, that once the mercurials reach the soil they break down fairly quickly so this protective effect of seed dressings is usually accepted to be in fact local sterilisation of the soil around the seed. If I might mention a few more points about the liquids as against the dust treatments, as we have found them in our work and without prejudice; the close adherence of the liquids as against the dusts is quite important. Once that liquid treatment is put on it is there to stay and the appearance of the seed is definitely better. There is a shine on seed treated with a mist or liquid as against the rather dusty look when it is treated with powder. The presence of the dye which so clearly indicates that the seed has had chemical treatment is a good thing, whereas the original powder disinfectants were usually made to blend with the seed because farmers apparently did not want a conspicuous label on the seed to the effect that it had been treated. However, as you know, you cannot wash off this treatment so that the practice which exists, at least in theory, of washing off the mercury from unwanted seed and then using it for feeding stuffs is out! A curious thing, however, is that I've never come across any merchant who definitely does wash off the mercury when it is in the powder form. I have a shrewd suspicion that one just "takes a chance", mixes a lot of untreated seed with a little of the treated and hopes that no harm will be done and probably in most cases it's not done. Last year when there was a good deal of talk about the killing of birds by certain poisonous seed treatments we were sent one sample of the "seed" which had caused trouble. Our report was that if anyone was using this as seed they were wasting good soil because it was a mixture of cereals and broken grain. It also included some which had been treated with a liquid mercurial, at least it had the red dye and therefore, of course, should not have been in any feeding stuff at all. We heard no more about that case.

Now I have been dealing with seed in this context as if it were a launching vehicle for the chemical which probably is fair enough but a rocket launching vehicle may properly be expendable in fulfilling its function. Seed must not be destroyed in this way or even injured because it is the source

of food for the seedling. Not only that, it is the source of the complex enzyme system governing its growth and I wonder just how much we know about the effect of chemical treatment on that, let alone the interaction of beneficial organisms as well as harmful organisms which are naturally present in and on the seed and the seedlings. It was shown a few years ago that the fungus Chaetomium, generally regarded as an insignificant saprophyte on cereal seed, is a natural antibiotic against Fusarium nivale which I mentioned earlier as a primary parasite. Chaetomium globosum had also proved to be antagonistic to the very serious disease of oats in America caused by Helminthosporium victoriae. Compared with our knowledge of the interaction of beneficial and other organisms present in the soil I think we know too little yet about these on seed and seedlings. Toxins developed by the parasites and antibiotics by seedlings are also part of this picture. Ludwig and his co-workers, for instance, found that an aqueous extract of young oat coleoptiles has high anti-fungal activity and that this disappears with age. Sometimes, to treat seed correctly we need accurate knowledge not only of the crop concerned but the particular lot or parcel of seed and you might even have to know the soil conditions into which it is to be sown. In this connection the observations made by Gibson in Tanganyika and Purss in Queensland on crown rot of groundnuts are significant. Gibson found that crown rot could be reduced by 50% using thiram on the seed where mercury failed not because of phytotoxicity but because of the selective action of mercury on the flora of the soil. Mercury-tolerant strains of the parasitic fungus were present and able to attack more effectively because of suppression of other soil-borne fungi. Again Purss in Queensland found that under certain conditions organo-mercurials actually increased the incidence of crown rot caused by Aspergillus niger. Here then is "local sterilisation" working in the wrong way. However, taking pre-emergence rot into account the organo-mercurials and captan gave most consistently good results so a combination is now used to give control both over pre-emergence rot and crown rot. Another similar interesting observation made by my colleague in Edinburgh, Hughes, is that dieldrin stimulates brassica seedlings so that they can be grown in soil infected with club root and although diseased yet give quite a good crop not so much because of the control of the disease but because of stimulation by the dieldrin. Again Roth, in Germany, working with beet found that mercury had a stimulatory effect apart from disease control. Concerning the practise of using the seed simply to carry chemicals into the soil I've sometimes wondered if a pellet of some inert substance or even dead seed carrying the fungicide or insecticide would not be a practicable method of getting them into the soil very near the living seed but without using the seed itself as the launching vehicle.

I referred to myself in the first instance as a Seed Pathologist and I am sorry to say that there are still so very, very few of us studying seed pathology in this country while there is so much to find out. The rate of progress in our study in Great Britain I'm afraid I can only call 'dead slow'. On the home front in the new Seeds Regulations we've managed to introduce one seed-borne disease of one horticultural crop. I understand,

of course, that there are many administrative difficulties but we in this country had better hurry up if we are to keep pace with international progress. I was recently in Paris at the Fourth International Meeting organised by the International Seed Testing Association's Plant disease Committee. We are studying methods of assessing the sowing value of seed, treated and untreated, in laboratory, glasshouse and field tests; work of considerable interest to all of you who are involved in the development and official approval of crop protection products. I know that in the very big screening programmes which you in the commercial world have to carry out you must restrict the number of your "guinea-pig" diseases and crops, but I would plead that you should not just use one sample of seed for this work and perhaps even just one disease. There are many seed-borne diseases still waiting for effective control. Of course through the new approval scheme which is a very great improvement on the original one, there will be opportunity for much wider testing of the new chemicals and it is through members of A.B.M.A.C. supporting the scheme and working with the advisory and official services such as the seed testing stations that we will eventually, and I hope a bit more quickly, come to a better understanding of the problems not only of those soil-borne diseases which may be controlled by seed dressings but of seed pathology.

INSECTICIDAL SEED DRESSINGS AND SOIL INSECTICIDES

by M.J. Way

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In 1945 Gough's classical review on soil insecticides was published in which the need for good soil insecticides was contrasted with the ineffectiveness or unreliability of existing chemicals. The 144 pages of the review included one paragraph on the use of calomel seed dressings against the onion fly, Delia antiqua (Wright, 1938, 1939) which at the time was the only evidence of insect control by seed dressings. Gough's survey makes interesting comparison with the present position (Lilly, 1956; Lange, 1959; Reynolds, 1958; Way 1959). Thus, in 1958 about 2 out of the 9 million acres of arable crops in Great Britain received insecticidal seed dressings, greatly exceeding the combined acreage of crops treated by all other methods of application. Furthermore, insecticides applied to the soil and to seeds are not only being widely used against many species of soil insects but some which act systemically are proving invaluable against insects attacking the aerial parts of plants.

These recent developments were initiated by Jameson, Thomas and Woodward's discovery (1947) that δ BHC seed dressings and soil insecticides could protect the young cereal plant from wireworm attack. δ BHC and other chlorinated hydrocarbons, notably aldrin, dieldrin and heptachlor have since proved outstanding against many other soil insect species whereas organophosphorus insecticides such as phorate, thiodemeton, dimethoate and menazon are being used as systemics against leaf and shoot feeders. The practical use of systemically acting soil insecticides is a comparatively recent development which has followed rather slowly from the original laboratory and field demonstrations of their efficiency and of their advantages over normal foliar applications for protecting the shoot of the young plant which is particularly vulnerable to insects and to insect transmitted diseases (Schrader, 1951; Ivy, Iglinsky & Rainwater, 1950; Ripper, Greenslade & Hartley, 1950; Jancke, 1951; David & Gardiner, 1951; Ashdown & Cordner, 1952; Way & Needham, 1957).

I will use the term seed dressing to include any pre-sowing application of dust or liquid insecticides to the outside of the seed. This includes soaking the seed in liquids as well as applying liquids as mists, sprays, large drops or slurries. Seed treatment should be regarded as a special method of applying a soil insecticide (Gough & Woods, 1954) though there are important differences. Besides being easy to apply, seed dressings are obviously well placed to protect the germinating seed and the young seedling plant. Thus, newly hatched larvae of the onion fly, (Delia antiqua) invariably enter the base of the shoot close to the position of the treated seed so that almost all are killed by contact with the seed dressing before they reach the plant (Way, 1959a). Similarly, against wheat bulb fly (Leptohylemyia coarctata) aldrin, dieldrin and heptachlor dressings at 3 oz active ingredient/acre can control the newly hatched larvae better than

aldrin or dieldrin combine;drilled with the seed at 24 oz/acre (Bardner, 1959); also for systemic action, seed dressings are immediately absorbed by the germinating seed or through the newly emerged root (David & Gardiner, 1955: Way, 1959a) in time to protect the emerging shoot, whereas a conventional soil application may sometimes fail to protect during the time taken for the roots to reach the insecticide in the soil (c./f. Burt, Broadbent & Heathcote, 1960).

The third advantage of seed dressings is the minute doses required for effective control. In the U.S A. 0.0062 mg of δ BHC per cereal seed (about $\frac{1}{4}$ oz per acre) is effective against wireworms (Lange, 1959) and rates as low as 1/100 oz per acre are apparently effective with other crops sown at lower seed rates. In Britain, Carden (1960) recommends dieldrin seed dressings at 3 oz on 6 lb seed per acre or about 0.1 mg per seed against the onion fly. This makes interesting comparison with recommended rates of dieldrin for wheat bulb fly control - about 3 oz dieldrin on 150 lb seed per acre or about 0.07 mg per seed. In view of the importance of the relationship between the insecticide and the seed it would seem that the common practice of giving the amount of insecticide as weight per weight of seed or as weight per acre is a less useful criterion of efficiency than weight per seed.

Seed dressing rates of 0.25 - 3 oz active ingredient per acre contrast with rates of 1 - 2 lb per acre required for control by conventional soil insecticides. Consequently seed dressings are cheap and, as they are so easily applied, it is not surprising that they have been widely used as a routine treatment.

Further advantages of seed dressings follow from the minute amounts needed for effective control. Thus there is no evidence that they do harm to beneficial insects unlike broadcast applications which can enhance Cabbage Root Fly (Erioschia brassicae) damage by killing its egg predators (Wright, Hughes & Worrell, 1960). Conventional soil insecticides may also cause notable changes in the general soil fauna (Satchell, 1955; Bollen, Morrison & Crowell, 1954; Sheals, 1956; Sanger, 1960), though there is little evidence that the induced changes in populations of Collembola, mites, earthworms and micro-organisms are harmful. On the contrary, they sometimes appear to stimulate growth (Zaki & Reynolds, 1961) I have noticed this with combine drilled treatments of dieldrin on wheat and of phorate and thiodemeton on field beans. There is also recent evidence that aldrin in pot experiments can affect the incidence of the soil borne disease of wheat Ophiobolus graminis. These subtle effects of seed dressings and soil insecticides have not been studied adequately nor has sufficient attention been paid to Ripper's (1956, 1957) important conclusions that both seed and soil applications of some systemic insecticides may do insignificant harm to natural enemies of insects attacking the aerial parts of plants in contrast to their effects as foliar sprays and I wish to exphasise the potential value of this type of selective action which for rational pest control is in general more realistic than the development of chemicals which are intrinsically highly selective.

Returning to seed dressings, the minute doses do not leave harmful residues or cause off-flavours in contrast to conventional soil applications of some insecticides which may persist too long and accumulate in the soil and in plants (Reynolds, 1958; McPhee, Chisholm & MacEachern, 1960; Lichtenstein, 1959a, 1959b; Lichtenstein & Polivka, 1959). For example, in Britain dieldrin at recommended rates for carrot fly (Psila rosae) control can accumulate in soil to levels which cause off-flavours, though Wheatley, Wright & Hardman (1960) have shown that this can be avoided by relating the amount of re-treatment to existing residues to maintain a level of about $1\frac{1}{2}$ lbs/acre which is adequate for carrot fly control. However, the insecticide pressure from soil residues which have been shown to remain toxic for many years to insects such as the carrot fly, flea beetles (Morrison & Crowell, 1959) and ants (Durr, Joubert & Walters, 1955) also favours the development of strains resistant to certain insecticides as has already happened with carrot fly and onion fly in parts of North America (Howitt & Cole, 1959; Finlayson, Crowell, Howitt, Scott & Wade, 1959). Insecticidal seed dressings would not favour the development of resistance in this way.

Unfortunately the valuable properties of seed dressings - ease of application, economy of use, lack of harm to beneficial organisms and no residue problems are offset by disadvantages. First, many are liable to be phytotoxic at much lower rates than would be harmful if applied as conventional soil insecticides. Phytotoxicity is enhanced by factors such as high storage temperature, moisture content and poor quality of seed which can however be alleviated. It also depends on the plant species; brassicae, for example, are relatively unaffected perhaps because the insecticides do not penetrate directly into the seed as shown by Bardner (priv. comm.) with phorate seed dressings on mustard seed. In contrast phorate readily penetrates seeds of wheat, which is much more susceptible. The nature of the seed dressing also affects phytotoxicity (May & Needham, 1957) and there is promising evidence that seed dressing carriers such as activated charcoal and stickers such as polyvinyl acetate can release the insecticide relatively slowly thereby lessening phytotoxicity and enhancing persistant action especially of systemic insecticides (Bardner, 1960).

Furthermore, some insecticides are comparatively non-phytotoxic - dieldrin for example - and although the doses of phosphorus insecticides that can be used have hitherto been limited by their phytotoxicity, it is a good omen that at any rate one new systemic - menazon - developed for aphid control appears virtually harmless to many plants. For example - seed dressings of active ingredient amounting to over 20% of the weight of the seed were harmless to field beans compared with some other systemic phosphorus insecticides which affected plant growth at under 0.1% of seed weight (Way, unpub.).

Another disadvantage of some chlorinated hydrocarbon insecticides is their harm to birds feeding on dressed cereal seed after drilling. Unfortunately this has been enhanced by widespread routine application

regardless of pest incidence. In 1958, for example, about three-quarters of the 2 million acres in Great Britain were sown with insecticide dressed seed. This problem should be solved not by restrictive legislation but rather by more accurate means of predicting damage so that insecticides are used only when necessary, and perhaps by the search for suitable bird repellents incorporated in the seed dressing.

I am not suggesting that seed dressings are always likely to be more effective for controlling insects than other methods of soil application. Seed dressings and soil insecticides may be best when used together as Dunn, (1960) has shown with endrin for lettuce root aphid, Pemphigus bursarius, control; also, although seed dressings will be increasingly used to give prolonged protection - for example, field beans can be protected from aphids throughout the season by a menazon seed dressing (Way, unpub.) - they may not always be placed in the best position for prolonged systemic action. Thus Burt, Broadbent & Heathcote (1960) showed that phorate combine drilled with the fertiliser, protected potatoes from aphids better and for longer than the same amount placed under the "seed" tuber. This is perhaps because lasting protection depends on continued uptake by roots, the absorbing region of which may sometimes grow beyond the area of the treated seed (Way & Needham, 1957) and also becomes concentrated where the fertiliser is placed (Cooke, 1954).

This kind of evidence emphasises our lack of the information on modes of action of seed dressings and soil insecticides which is needed if they are to be used to the best advantage. We do not know why, for instance, the highly toxic phosphorus insecticides such as phorate and thiodemeton have, with few exceptions (Jepson & Mathias, 1960) proved ineffective against soil insects; also little is known about how seed dressings affect wireworms despite over twelve years of use. Wireworms attacking the ungerminated or newly germinated seed may be killed by the insecticide on the seed (Lange, Carlson & Leech, 1949; Kulash & Monroe, 1954; Starks & Lilly, 1955; Long & Lilly, 1958) but in the older plant wireworms attack the shoot, not the seed and although not always killed by a seed dressing they may be deterred presumably by the insecticide acting systematically in the shoot. This is suggested by the results of experiments by Potter, Healy & Raw (1956). 1.2 oz of δ BHC per acre applied as a seed dressing was compared with soil treatments when the insecticide was combine drilled with the seed at 6 oz δ BHC and broadcast at 1 lb δ BHC per acre on plots of wheat drilled in November. Next year the plots were redrilled without further treatment. Results in table 1 show that although in the first year the seed dressing gave a good response in yield it did not kill the wireworms which severely damaged the subsequent untreated crop.

Wireworms, which occur in overlapping generations and may each spend five years in the soil feeding on many different plant species before pupating, contrast with soil inhabiting larval Anthomyidae and Chloropidae (Diptera) which are mostly specific in their choice of host plants, usually appear only after the host is planted and develop from egg to pupa in 2 - 8 weeks. Unlike wireworms they would soon die of starvation if deterred by

an insecticidal seed dressing, so that kill by "contact-action" could be either direct or indirect through starvation.

Table 1. Comparison of Different Soil Applications of γ BHC for Wireworm Control. (Potter, Healy & Raw, 1956)

		1st year	2nd year	
Method of application	Dose per acre	Crop yield/ cwt per acre	Crop yield/ cwt per acre	Log.no.of wireworms per plot
Seed dressing	1.2 oz	24.0	24.2	3.73
Combine drilled	6 oz	24.8	37.3	2.2
Broadcast	1 lb	30.6	39.6	1.33
Untreated	-	8.9	28.4	3.3

Three species of Diptera, the onion fly, Delia antiqua, the wheat bulb fly, Leptohylemyia coarctata and the frit fly, Oscinella frit have larvae which mainly feed inside the underground parts of the shoot of seedling ionions, wheat and oats respectively. They damage or destroy the growing point and kill or stunt the plants and provide an interesting series illustrating the ways in which seed dressings act (or fail to act) against soil insects.

I have already mentioned that the newly hatched onion fly larvae burrows down through the soil to the underside of the onion shoot where it almost invariably enters close to the position of the treated seed. This happens even if the seed is deeply sown and thus, regardless of sowing depth, a suitable seed dressing will give virtually complete kill by contact action before the larva reaches the plant. For example, Table 2 shows that 0.04 mg dieldrin per seed gave almost complete protection to onions from treated seed sown at both $\frac{1}{4}$ and 1 in.

Table 2. The Effect of Sowing Depth on the Action of Insecticidal Seed Dressings Against Three Species of Dipterous Larvae

Insect species	Insecticide and dose per seed (mg)	Depth of sowing (in.)	*Damaged plants	*Living larvae
Onion Fly	Dieldrin (0.04)	$\frac{1}{4}$	2	0
		1	6	2
Wheat Bulb Fly	Dieldrin (0.086)	$\frac{1}{2}$	49	0
		3	76	22
	δ BHC (0.086)	$\frac{1}{2}$	3	0
		3	66	78
Frit Fly	Dieldrin (2.0)	$\frac{1}{4}$	36	30
		1	105	107

* Given as percentages of the numbers in untreated "controls"

Wheat bulb fly larvae, however, enter the shoot about $\frac{1}{2}$ - 1 in. below the soil surface regardless of the sowing depth of the seed. This suggests that kill by contact is likely to be best if the seed is sown shallowly and the figures for damaged shoots (Table 2) confirm this for both dieldrin and δ BHC. However, of the larvae that entered and damaged the shoots of dieldrin treatments comparatively few or none survived. For example, with seed sown at $\frac{1}{2}$ in. the number of damaged shoots was 49% of those in the "controls" but no larvae survived and many were found dead in the damaged shoots. Experiments in which parts of plants from dieldrin dressed seed killed larvae in circumstances which excluded kill by contact showed that dieldrin in lethal quantities was acting systemically after uptake from the seed (Way, 1959a). This was confirmed using labelled dieldrin. It is well known that δ BHC is taken up systemically from seed dressings and from the soil (Bradbury & Whitaker, 1956; Jameson, 1958) and it now seems that the limited systemic action of several chlorinated hydrocarbon insecticides can be a very important factor in their control of soil insects (e.g. Gough & Woods, 1954; Walker, 1960). This makes it even more surprising that true systemic phosphorus insecticides are generally ineffective and it can only be assumed that the latter are translocated so quickly to the leaves that they fail to reach lethal concentrations in the stem or underground parts of the shoot.

It is interesting that 0.04 mg dieldrin per onion seed gave much better control of onion fly than 0.086 mg dieldrin per seed against wheat bulb fly, although, as mentioned earlier, the recommended field rates are similar. This is because in practice against wheat bulb fly, dieldrin kills mainly by systemic action and since this can only happen after the insect has fed, it cannot prevent damage like a treatment which kills by contact action outside the plant. However, it is fortunate that this initial damage can often be tolerated because the wheat plant, unlike the onion, can compensate by

extra tillering so that yields may be unaffected despite apparently serious damage.

The third example (table 2), that of seed dressings against the frit fly, (Way, 1959b) shows that a very high dose of 2.0 mg of dieldrin per seed killed some larvae by contact with treated seed down at $\frac{1}{4}$ in. depth but those larvae which entered the shoots were unharmed by systemic action. Consequently at 1 in. sowing depth, dieldrin was ineffective both systemically and by contact since apparently all larvae entered the shoot well above the position of the treated seed. The failure of dieldrin seed dressings to act systemically against frit fly larvae is inexplicable especially as they are highly susceptible to dieldrin sprays and behave like wheat bulb fly larvae after entering the shoot; also this effect is not specific to oats since dieldrin dressings on wheat also failed against frit fly.

Despite these anomalies we can conclude that seed dressings may kill insects by contact action if they pass close to the treated seed and that this action might be direct, or indirect through starvation after the insect is repelled. The limited systemic action of chlorinated hydrocarbons may also be very important in the control of some soil insects and is usually the sole factor in the action of soil applied systemic phosphorus insecticides though mechanical transport may sometimes be important. For example, Jameson (1958) has shown that the colyledons may collect particles of insecticide from the surface of the seed and carry them above the soil surface as the plumule elongates.

You will appreciate that the work on mode of action which I have mentioned is incomplete and some of the evidence needs confirmation. But, at least it typifies the inadequacy of present knowledge of the many biological physical and chemical factors that must be better understood if we are to use seed dressings and soil insecticides to the best advantage.

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RESULTS OF EXPERIMENTS WITH SYSTEMIC INSECTICIDAL SEED DRESSINGS

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There is much current interest in controlling insects attacking the foliage of plants by the use of systemic insecticides applied to seed or to the soil. These methods are particularly suitable to control sucking insects like aphids, but may also be useful against chewing insects like flea beetles and cut worms. The idea is not new, but only recently have suitable insecticides been available in Britain. As yet, no materials have received official approval for use in this way.

The conventional methods of spraying or dusting the foliage of young seedlings have several disadvantages that might be overcome by the use of seed or soil treatments. Irregular germination may mean that more than one dusting or spraying is needed to cover all the plants at an early stage of growth. The area of the foliage of young plants is only a small fraction of the ground area, so that most of the insecticide falls on the soil may be wasted. Rapid growth can soon dilute and render ineffective the insecticide which does reach the plant. With systemic insecticides applied to seed or soil the plant is usually toxic to insects from germination onwards. The reservoir of insecticide below ground can keep the plant toxic for a long period, 3 - 8 weeks being the usual range for seed dressings.

Soil applications are usually more persistent and less phytotoxic than seed dressings, but needing 5 - 10 times as much insecticide, and it is less certain that the plant will be toxic on germination, the plant often taking a few days to attain its maximum toxicity.

Systemic insecticides applied to seed and soil have been used extensively in North America to prevent mechanical damage by insects to plants such as cotton and alfalfa (See reviews by Lange (1959) and Reynolds (1958)). It is likely, however, that one of their principal uses in the U. K. will be to prevent early infections with insect-transmitted viruses in such crops as sugar-beet and potatoes. (Burt, Broadbent & Heathcote 1960). Aphids are the principal vectors of these viruses and nearly all systemic insecticides are effective against aphids. Most systemic insecticides belong to the organophosphorus group.

To use these materials to their best advantage it is necessary to know how they are absorbed by the plant and what factors are likely to affect the length of time for which the plant remains toxic to insects. For seed dressings knowledge of this kind is particularly important. As the dose is small and concentrated near the plant they tend to be more phytotoxic and less persistent than insecticide applied to soil. This paper describes the results of simple experiments on plants grown in the glasshouse in

which seeds of wheat or white mustard were treated with phorate and the toxic effects measured by caging insects on the plants grown from these seeds. The extent to which the results obtained are generally applicable is considered after describing the experimental results.

Materials and Methods

Phorate, diethyl S-(ethylthiomethyl) phosphorothiolothionate, is an oily liquid of low water solubility (50 parts per million) and with a vapour pressure similar to that of parathion to which its mammalian toxicity is also comparable. It decomposes in the plant and the soil fairly rapidly, but the primary decomposition produces are themselves insecticidal, so that the systemic effect lasts a long time.

Wheat and mustard seeds were used for the experiments because of their contrasting structure and germination. Wheat seed is hypogeal and monocotyledonous, with a large endosperm. The seed remains buried in the soil and attached to the plant, which absorbs from it for some time after germination. Mustard seed is a dicotyledonous epigeal seed with no endosperm. The cotyledons contain the food reserve but emerge through the soil to form the smooth leaves, leaving the empty seed coat behind.

Wheat seeds were treated with a slurry composed of 0.4 g technical phorate, 4 g silicious earth filler and 6 ml 3% methyl cellulose in water per 100 g of seed. Mustard seed was treated with a slurry containing 4 g technical phorate 12 g siliceous earth and 12 ml 3% methyl cellulose solution per 100 g seed. Wheat seeds weighed 53 mg and mustard seeds 7.5 mg. The dose of insecticide in milligrams per seed was very similar, 0.21 for wheat and 0.30 for mustard, but in terms of milligram per milligram of seed the dose was 10 times as great on mustard as on wheat.

Seeds were usually planted in 5" plastic pots or standard seed boxes filled with John Innes No. 1 compost and kept in a heated glasshouse. Insecticidal effect was tested by caging adult or late instar aphids on the plants, the bird cherry aphid Rhopalosiphum padi being used on wheat and the mealy cabbage aphid Brevicoryne brassicae on mustard (for fuller details see Bardner 1960).

Results

The experiments and their results will be described in chronological sequence of the stages from the time the seed is treated with insecticide until it reaches the foliage on which the insects are feeding.

When a slurry consisting of the insecticide, filler, sticker and water is applied to the seed and allowed to dry it seems probable that some of the insecticide, being an oily liquid of high vapour pressure, would pass through the seed coat into the seed. As described below, this probably happens with wheat seed, but not to any significant extent with mustard.

Mustard seed was treated with a phorate slurry. After this had dried the seed was stored for three days. Seeds were then put on damp filter-paper for three hours. The seeds absorbed water, the seed coat becom-

ing soft. The seeds were washed briefly in water and the seed coat was dissected off, the embryo being planted in the soil. Plants treated in this way were not toxic to aphids, although plants grown from seeds that were washed but had the seed coat left intact were toxic. Thus the seed coat prevents any significant amount of phorate from reaching the embryo of mustard seed before germination.

It is difficult to devise an equally conclusive experiment with wheat, and the evidence for penetration into the seed is less direct. Untreated seeds of wheat were planted in sand. When the coleoptile of the seedling was $1\frac{1}{2}$-2" long the seedlings were removed and washed thoroughly in running water, leaving the seed attached to the plant. The plant and the seed was blotted dry and a dose of phorate slurry at the normal rate applied with a micro-syringe to the exterior of the seed, care being taken to see that the roots and coleoptile were not contaminated. The plants were then suspended over culture solution into which the roots but not the seeds dipped. Even when care was taken to exclude the possibility of fumigant action plants with treated seeds killed aphids. This experiment shows that phorate from a slurry applied to wheat seed can penetrate into the seed and be directly translocated to the foliage.

When the seed is planted it absorbs water and swells in the process of germination. The sticker in the coating of insecticide slurry is water-soluble so that, shortly after planting, the slurry particles are only loosely attached to the seed and can pass into the soil. This process is assisted by the germination of the seed. Insecticidal activity can be detected in the soil at a greater distance from live treated seed than from heat-killed treated seed.

Several lines of evidence confirm this:- The anti-cholinesterase activity in soil caused by the spread of insecticides from the seed can be detected by placing a gelatine-coated glass plate in contact with a vertical soil profile. The gelatine will absorb insecticide, and when the plate is removed and pressed against a filter paper soaked in an aqueous suspension of insect esterases the inhibitory action of the insecticide can be detected by a colorimetric method (Bardner et al., unpub.). The method is sensitive to roughly 1 part in 10,000 of phorate. So far, only wheat seeds have been tested, but the area of inhibition round the seed is greater with seeds treated alive than dead. Similarly if wheat or mustard seeds are treated with a slurry containing a water insoluble fluorescent dye (Fire Orange) instead of insecticide, a vertical soil profile will show that the dye is spread over a wider area with live than with dead seeds. Particles of fluorescent dye are not carried by the roots, and tests in which roots from plants grown from treated seeds dip into water containing young mosquito larvae show that the roots do not excrete insecticide.

When untreated wheat or mustard seeds are grown $\frac{3}{4}$"-$1\frac{1}{2}$" away from treated seeds, plants from untreated seeds pick up enough insecticide to become toxic to aphids, and this effect is more pronounced near live treated seeds than near dead treated seeds.

Mustard seedlings, unlike wheat, can acquire insecticide by surface

contamination of the cotyledons as they emerge through soil containing insecticide derived from a seed dressing. Mustard seeds were treated with a slurry containing Fire Orange and planted in soil. Examination of the young seedlings under ultra-violet light showed that the cotyledons and the upper part of the hypocotyl were covered with particles of dye. Coleoptiles of wheat grown from seed treated in a similar manner occasionally have a few particles near the base of the coleoptile, but this is insignificant compared to the amount on mustard seedlings.

The reservoir of insecticide present in the soil but derived from the seed dressing is very important for the continued toxicity of the plants.

Treated wheat and mustard seeds were grown in soil and transplanted at various intervals after sowing, the roots being thoroughly washed before replanting. Transplanted plants lost their toxicity much sooner than undisturbed plants. For example, mustard plants transplanted 11 days after sowing, when the 2nd pair of rough leaves were just appearing, were tested 22 - 26 days after sowing. Both the cotyledons and the first pair of rough leaves were still killing all aphids, but the "killing index" =

$$\left(1 = \frac{\text{mean square root of aphids on treated}}{\text{mean square root of aphids on untreated}}\right) \times 100$$

was 81 for the cotyledons of the transplanted plants and 41 for the rough leaves (complete control = 100). With both wheat and mustard, new leaves produced after transplanting were not toxic. Leaves and cotyledons formed before transplanting lost their toxicity quicker than those of undisturbed plants. Removing the wheat grain before transplanting sometimes accelerated this loss, but cutting the union between the seed and the coleoptile in otherwise undisturbed plants did not affect it.

These experiments show that to become and remain toxic all the leaves depend to some extent on continued uptake of insecticide from the soil and that insecticide is not translocated in toxic amounts from old to young leaves.

The distribution and availability of the insecticide to the soil will be affected by soil conditions. Soil insecticides and seed dressings are less effective in soils containing much organic matter. Leaching can also have a big effect on the time for which the plants remain toxic and these two factors interact with one another.

Treated wheat seeds were grown in pots containing a fen peat soil and sand mixed in various proportions by volume:- 100% peat, 50% peat, 10% peat and 100% sand. Half the pots received a standard culture solution watered on to the soil daily ("leaching"), and half were stood in dishes containing culture solution ("no leaching").

Under no-leaching conditions the amount of insecticide available to the plant and hence the time for which it remains toxic was least with 100% peat and most with 100% sand, but under leaching conditions the intermediate mixtures of peat and sand gave the longest toxicity. Similar results were obtained with mixtures of sedgemoor peat and sand. When

mixtures of clay and sand were tried, the clay was found to have no effect under non-leaching conditions, and only a slight effect under leaching conditions.

These experiments show that soils containing much organic matter absorb insecticides and either release it slowly or retard the process of leaching. Prevention of leaching by interference with free drainage seems to be the only effect of a high clay content.

Discussion

The experiments on seed dressings described here were limited to one insecticide (phorate) in one particular type of formulation applied to seeds of two plant species only. Nevertheless, they showed the way in which the insecticide reached the plant could differ greatly. These differences seem especially important in the very early stages of the seedlings growth, older seedlings being dependent on the continued uptake of phorate from the reservoir in the soil. Phorate in the aqueous slurries used in the experiments can penetrate the seed coat of wheat, but although it is absorbed to a certain extent by the seed coat of mustard it cannot pass into the embryo in insecticidal quantities until after germination. Perhaps this explains why brassica seedlings tolerate large insecticidal seed dressings. The experiments revealed that the cotyledons of mustard can pick up particles of seed-dressing on their way through the soil, a deduction used by Jameson (1958) to explain how relatively poor systemics like lindane were so effective on kale seed against flea beetles.

What the mechanisms of uptake are when dicotyledonous hypogeal seeds such as field beans are treated with systemic insecticide slurries is at present unknown, nor is it known whether young wheat and mustard seedlings can immediately absorb the insecticide present in the soil or whether this has to wait upon the development of an absorptive root system.

There is evidence that the mode of action of other formulations and methods of application may differ. Bardner (1960) has shown that with insecticidal slurries fillers can be used which adsorb insecticide and release it slowly over a long period, so that under suitable conditions phytotoxicity can be reduced and insecticidal persistence lengthened. Preliminary work in which phorate in the usual slurry formulation applied to wheat was compared with a liquid formulation of phorate in cyclohexanone and an aqueous emulsion of a liquid formulation of phorate indicated that the slurry formulation was more easily leached away but under non-leaching conditions was much more persistent. Differences in persistence and resistance to leaching probably reflect differences in penetration into the seed.

As much of the insecticide from slurry seed dressings passes into the soil, persistence is greatly affected by soil factors such as structure, amount of organic matter and water movements, and also by the water solubility of the insecticide and its decomposition products. If high seeding rates are used, so that the seeds are only $\frac{3}{4}$" or so apart, some rein-

forcement of insecticidal and phytotoxic effects must be expected and this will be most noticeable in sandy soils containing little organic matter. Persistence of insecticidal effect will probably be brief with seedlings grown in sandy soils and irrigated to excess.

Because oldest leaves retain their toxicity longest, the persistence of insecticidal effect may depend on the behaviour of insects attacking the plant.

Aphids normally colonize the youngest foliage of seedlings. They may be able to survive and reproduce where more mobile and less discriminate feeders such as flea beetles would be killed by insecticide still present in the older leaves.

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STUDIES OF EFFECT ON GERMINATION OF CERTAIN SOLVENTS USED IN EXPERIMENTAL LIQUID INSECTICIDAL SEED DRESSINGS APPLIED TO CEREALS WHICH HAVE RECEIVED A STANDARD APPLICATION OF A LIQUID ORGANO-MERCURIAL COMPOUND

by H. D. H. Womack

Shell Chemical Co. Ltd.

Introduction

During the war and for a number of years afterwards, the crop losses due to wireworm (Agriotes spp.) were considerable. It had been found by Jameson, Thomas and Woodward (Ann. appl. Biol. 1947, 34, 346.) that BHC when applied to cereal seed prevented damage by this pest and in 1948 a powder dressing based on this insecticide and containing an organo-mercurial fungicide was introduced to the market. Seed dressings of this nature have been generally termed 'Dual Purpose' because control of certain soil borne and seed borne diseases is also achieved. Subsequently, dual purpose powder seed dressings containing aldrin, dieldrin and heptachlor were placed on the market and widely used.

When liquid organo-mercurial seed dressings were first introduced into the U. K. it was appreciated that there would be a demand for seed to be treated not only with the fungicide but also with an insecticide to give the necessary measure of control of wireworm. Whilst the simplest method of dealing with this problem is to formulate a dual purpose liquid, such a product has the disadvantage that the ratio of the insecticide to the organo-mercurial compound is fixed. However, if two separate liquid formulations are employed and applied separately to the seed, then the ratio of the organo-mercurial compound to insecticide can be varied by mechanical means. This variation in ratio is of importance if the same liquid insecticide is to be employed for the prevention of damage by wireworm as well as damage by Wheat Bulb fly. Trials previously carried out in East Anglia and East Midlands by the N. A. A. S. have clearly shown that a higher concentration of insecticide is required for the protection of the seed against attack by Wheat Bulb fly than by wireworm.

Because the insecticides normally employed for treating seed against these pests are chlorinated hydrocarbons, a solvent with a high solvent power for this type of chemical has to be employed. The solvent in a liquid insecticidal formulation should have the following characteristics:- (1) virtually no phytotoxicity to the seed; (2) compatibility with the solvent used for the organo-mercurial compound; (3) good solvent power for the chosen insecticide at low temperatures; (4) good stability in the formulation.

Other important characteristics of the solvent are:- (a) absence of high inflammability; (b) safety in handling in confined spaces; (c) a sufficient volatility to prevent the seed remaining coated with the liquid for a pro-

longed period; (d) absence of adverse effects on germination if the seed is stored for a lengthy period

Method

All the tests referred to in this report were carried out either by the National Institute of Agricultural Botany at Cambridge or by the Department of Agriculture for Scotland Seed Testing Station at East Craigs. In nearly all cases the figures were those from the normal routine soil tests carried out by the station concerned. Untreated control samples were sometimes also treated with the dye alone and sometimes all the samples were treated with colourless solutions only. The reason for doing this was to prevent the possibility of slight, but nevertheless normal, symptoms being classified as abnormal in the germination tests. Reports were received where 'abnormals' appeared in the untreated control samples.

An indication of the effect of a liquid insecticidal seed dressing is given by the percentage of 'abnormals' appearing in a sample. However, many abnormal seedlings may grow to a normal healthy plant because any abnormality in the developing seedling, whether slight or gross, is reported under this single heading.

As large a number of cereal varieties as possible have been used in the tests. Only when normal farmers quality seed of the variety to be tested was not obtainable, was high quality or once grown seed used. It was appreciated that the use of such seed might result in greater loss in germination and increase the percentage of abnormals but it had the advantage of showing what results might be expected under typical conditions.

In practically every case the seed was treated in a liquid seed treating machine in order that the results might be as nearly comparable as possible with those that would occur in seed dressing establishments.

Samples were either taken at random from the flow of grain as it left the seed treater or by drawing off samples from the centre of the sack. The samples were sent to the seed testing station under code. Treated seed retained for storage trials was packed in multi-wall paper sacks, the opening being folded over and tightly tied to prevent any loss of solvent.

Trials Results

As it was planned that the liquid insecticide should be applied to the seed at the rate of 1 fl.oz per bushel, solubility of the insecticide in the solvent was the first consideration in the selection of potential materials. The solvents concerned in this report are shown in Table 1 with some of their more important characteristics:

Table 1

	HCS*	Carbon tetra-chloride CT	Dimethyl formamide DMF	Cyclo-hexanone CX
Specific Gravity	0.877 at 15/15°C	1.59 at 20/4°C	.953 at 15/15°C	.948 at 20/4°C
Aromatic Content	98%	-	-	-
Flash Point	117°F	Non. inflam.	153°F	147°F
Distillation Range	162° - 180°	-	-	-
Boiling Point	-	77°C	153°C	156°C
Vapour Pressure	above 10 mm Hg at 20°C	91 mm Hg at 20°C	3.7 mm Hg at 20°C	10 mm Hg at 38°C
Solubilities in g/100 ml of solution at 25°C				
DIELDRIN	32g	38g	46g	49g
ALDRIN	73g	105g	55g	69g
LINDANE	23g	7g (20°C)	40g	49g

*HCS = Fully refined petroleum-derived Hydrocarbon solvent.

Another and almost equally important consideration was the low temperature storage stability of the solutions since treatment of cereal seed is carried out during the winter months. In periods of prolonged frosts the temperature in some seed dressing establishments can fall below 0°C. Table 2 shows the results obtained when certain formulations containing 30% dieldrin were subject to cold storage stability tests; the formulation passed the test if no dieldrin was deposited from solution when stored 48 hours at -5°C.

Table 2

H.C. Solvent % vol/vol	Chemical Solvent % vol/vol	TEST RESULTS 48 hours at -5°C
0	100% cyclohexanone	Passed
30%	70% "	"
80%	20% "	Failed
100%	0% "	"
0	100% carbon tetrachloride	"
30%	70% " "	"
60%	40% " "	"
80%	20% " "	"
0	100% dimethyl formamide	"
30%	70% " "	Passed
60%	40% " "	"
80%	20% " "	"

Those formulations that passed the cold storage test, together with some of those that failed, were applied to three varieties of cereals to assess the effect on germination and degree of phytotoxicity. The results of these tests are shown in Table 3:

Table 3

Rate of application - 1 fl.oz per bushel

	Wheat "Eclipse"				Barley Pioneer				Oats S147			
	N	Ph	Ab	D	N	Ph	Ab	D	N	Ph	Ab	D
Untreated	97	-	2	1	94	-	3	3	96	-	2	2
30% dieldrin in 100% CT	97	-	2	1	97	-	2	1	92	8	8	-
70% " + 30% HCS	95	T	3	2	92	-	4	4	94	-	4	2
100% CX	96	-	2	2	93	-	4	3	94	-	3	3
70% " + 30% "	93	-	5	2	91	-	4	5	90	-	6	4
40% " + 60% "	96	-	4	-	91	T	5	4	92	-	3	5
100% DMF	98	-	1	1	91	3?	5	4	99	-	1	-
70% " + 30% "	97	-	3	-	93	-	3	4	93	5	7	-
40% " + 60% "	96	-	4	-	91	T	5	4	92	-	3	5
20% " + 80% "	95	-	4	1	89	3	7	4	88	10	10	2
100% HCS	94	4	4	2	89	4	4	7	87	5	7	6

Abbreviations used in the Tables: N = Normal germination; Ph = Phytotoxicity; Ab = Abnormal germination; D = Dead seeds; T = Trace less than 1%.

Straight varietal testing at normal rates of application is of greatest value but it may not show up the adverse effects that could arise if accidental overdosing should occur under practical donditions. Table 4 shows the effects of normal application and overdosing on a number of oat varieties with 30% dieldrin solutions; together with the effects of this overdosing during storage.

Table 4

	Rate	After one months storage			After four months storage		
	fl. oz/ bushel	N	Ph	Ab	N	Ph	Ab
Untreated		97.0	-	1.3	97.7	-	1.0
Organo-mercury only		98.3	-	1.0	96.6	T	1.6
+ 60/40 HCS/CX	1.	96.7	-	2.5	96.6	T	1.7
" "	2.	95.0	-	3.3	97.0	T	1.3
" "	3.	95.0	-	3.2	96.0	1.3	1.0
+ 100% CX	1.	97.0	-	2.0	96.7	Nil	1.6
"	2.	96.3	-	2.7	97.3	1.0	1.3
"	3.	95.0	-	3.0	97.2	1.0	1.0
+ 80/20 HCS/DMF	1.	97.7	-	1.6	96.7	Nil	1.0
" "	2.	96.0	-	3.2	97.3	T	1.0
" "	3.	96.3	-	3.0	97.4	T	1.3

Subsequent parallel trials using aldrin as the insecticide gave results not materially different from those obtained with dieldrin. The result confirmed that the solvent or solvent mixture is likely to have some effect and to emphasise this, a still higher dosage rate was employed. Table 5 shows the averaged effect on a number of oat varieties of a 30% aldrin solution in a mixture of 60% HCS and 40% CX, immediately after application and during storage.

Table 5

	Immediate		After one months storage		After two months storage	
	N	Ab	N	Ab	N	Ab
Untreated	90.5	3.8	90.3	3.2	92.8	2.0
Organo-mercurial only	91.5	3.8	92.0	2.2	90.8	6.3
30% aldrin in 60/40 HCS/CX						
at 1 oz/bushel	92.8	2.0	91.2	4.0	91.3	3.0
at 2 oz/bushel	90.5	5.0	87.7	4.7	93.8	2.3
at 4 oz/bushel	83.3	10.5	84.2	9.0	87.5	6.8

Lindane

Many tests were carried out to check the reported phytotoxicity of lindane seed formulations. Table 6 shows the results obtained in a trial using lindane and lindane/aldrin mixture in various solvents and mixtures of solvents. 30% lindane solutions were employed in this series of trials in order that some comparisons could be made with the known effect of 30% aldrin and dieldrin solutions although it was known that such a solution would not be suitable from a low temperature stability point of view. Rates of $\frac{3}{4}$ and $1\frac{1}{2}$ fl. oz per bushel were employed in order to be able to obtain bracket assessment of the effects of a 1 fl. oz per bushel rate.

Table 6

		Wheat. av: 5 varieties				Barley 3 varieties				Oats 3 varieties			
	fl. oz per bushel	no storage		1 month storage		no storage		1 month storage		no storage		1 month storage	
		N	A	N	A	N	A	N	A	N	A	N	A
Untreated	-	95	0	96	0	96	0	95	0	95	0	95	0
Organo-mercury only	$\frac{3}{4}$	93	2	95	1	95	0	97	0	96	0	93	0
+ 30% lindane in CX	$\frac{3}{4}$	95	3	91	5	95	0	93	1	94	3	95	2
" " " "	$1\frac{1}{2}$	87	9	96	9	95	0	89	5	93	3	95	3
20% " 10% aldrin in CX	$\frac{3}{4}$	94	3	90	4	97	0	96	0	92	1	93	2
" " " " "	$1\frac{1}{2}$	91	5	93	4	95	1	92	3	93	3	91	4
30% " in 60/40 HCS/CX	$\frac{3}{4}$	95	2	96	3	98	0	95	0	95	0	95	3
" " " " "	$1\frac{1}{2}$	93	5	90	5	94	2	92	2	94	4	93	3
20% "/10% ald in 60/40 HCS/CX	$\frac{3}{4}$	93	2	92	4	95	1	95	1	95	0	94	2
" " " " "	$1\frac{1}{2}$	94	2	91	3	95	0	94	1	91	5	92	5
30% " in DMF	$\frac{3}{4}$	95	3	90	7	96	0	93	2	97	0	93	2
" " "	$1\frac{1}{2}$	95	3	89	5	94	0	94	0	94	3	94	2
20% " 10% ald in DMF	$\frac{3}{4}$	96	2	94	2	97	0	95	0	95	0	96	1
" " " "	$1\frac{1}{2}$	94	1	92	3	94	0	93	2	95	1	94	2

A further trial employing higher rates of application confirmed that 30% lindane in CX and CX + HCS were liable to be phytotoxic at rates of application over 1 fl. oz per bushel.

The indications from this and other trials showed that lindane formulated with DMF is less liable to produce abnormalities in the developing seedling. There were also indications that the addition of aldrin to lindane might reduce the phytotoxicity of the latter material.

Table 7

Mean of 3 varieties

	Rate fl. oz per bushel	no storage		one months storage	
Untreated	-	93	0	95	0
Organo-mercurial only	normal	95	0	93	0
+ 30% lindane in CX	1	90	6	80	12
" " " " "	2	84	12	70	22
" " " " "	4	50	48	46	42
" 20% " 10% Ald in CX	1	94	2	91	2
" " " " "	2	84	8	84	9
" " " " " "	4	70	27	68	22
" 30% " in 60/40 HCS/CX	1	93	1	88	5
" 20% " 10% Ald in 60/40 HCS/CX	1	93	2	89	6
" " " " " " "	2	95	3	85	10
" " " " " " "	4	61	35	72	15
" 30% " in DMF	1	90	2	87	4
" 20% " 10% ald in DMF	1	95	3	90	6

Trials using 25% lindane in DMF at 1, 2, and 3 fl.oz per bushel on cereal varieties liable to damage by lindane indicated that this solvent is less likely to produce phytotoxic symptoms if overdosing occurs and Table 8 shows that DMF applied alone does not produce any significant number of abnormalities in the germinating seedlings or reduce the germination capacity.

Table 8 also shows that a 25% lindane in DMF solution at 1 and 2 fl.oz per bushel does not produce any significant reduction in germination nor materially increase the very small percentage of 'abnormals'.

Table 8

Average of 6 varieties

	Rate in fl.oz/bu	no storage		one months storage	
		N	Ab	N	Ab
Untreated		94.5	0	95.0	0
25% lindane in DMF		91.2	1.1	94.6	1.6
" " "		92.6	2.4	93.3	2.1
" " "		87.3	5.7	87.5	7.7
DMF alone		93.8	0.1	94.0	0.3

Discussion of Results

The application of a 30% aldrin or 30% dieldrin liquid insecticidal seed dressing based on certain solvents had no significant harmful effect if applied to barley and oat seed at up to 2 fl. oz per bushel. It therefore appears that these two insecticides, in liquid formulations, are virtually non-phytotoxic to seed of good germination capacity provided the solvent employed is also non-phytotoxic.

Cereal seed treated with liquid seed dressing containing 30% aldrin or 30% dieldrin can be stored safely for at least two months without materially affecting the germination capacity.

A 30% lindane in cyclohexanone liquid seed dressing formulation can cause abnormalities in germinating seedlings at all tested rates of application. This phytotoxicity appears to be reduced when aldrin replaces part of the lindane in the formulation. Furthermore, the replacement of part of the cyclohexanone by a suitable hydrocarbon solvent also appears to reduce the phytotoxicity of the former solvent to some extent.

When dimethyl formamide is wholly or partly employed as the solvent in a lindane liquid seed dressing then the phytotoxicity associated with this insecticide is reduced to almost insignificant proportions provided the rate of application is not appreciably greater than 1 fl. oz per bushel.

Unlike aldrin and dieldrin liquid seed dressings, those based on lindane tend to reduce, during prolonged storage, the germination capacity of cereal seed, particularly some varieties of wheat. Field trials (not reported here) comparing seed treated with a solution of lindane in dimethyl formamide with seed dressed with commercially available products, have confirmed the safety of such a formulation.

Summary

Cereal seeds were treated with solutions of aldrin, dieldrin or lindane in various solvents and mixtures of solvents. Germination tests were carried out on the treated seed to assess the degree of phytotoxicity that might arise under practical conditions.

Solutions of aldrin or dieldrin in cyclohexanone or in a mixture of this solvent and a hydrocarbon solvent produces no significant adverse effects at normal or up to three times normal rates of application. When solutions of lindane in cyclohexanone or in mixtures of cyclohexanone and a hydrocarbon solvent were applied to cereal seed, damage occurred, which was not the case when solutions of lindane in dimethyl formamide were applied at 1 fl. oz per bushel.

In storage trials, seed treated with solutions of aldrin or dieldrin in dimethyl formamide or cyclohexanone did not show any significant adverse effects. Lindane in dimethyl formamide tends to produce adverse effects if the treated seed is stored for prolonged periods.

Discussion

Q. Mr. D. Rudd Jones

As I understand it, there are certain internal fungal diseases of seed which are not controlled because the fungicidal seed dressings are not normally systemic and I am wondering in view of the increasing popularity of liquid dressings whether this might be taken a stage further and attempts made to control internal fungal parasites by fumigation. Is Dr. Noble aware of any use of fumigation to control seed borne diseases and can she tell me what fumigants might be fungitoxic and non-phytotoxic in the treatment of seed?

A. Dr. M. Noble

I am afraid I have very little first-hand information about this but methyl bromide has been tried, particularly in connection with nematode treatment of Medicago, and some of my colleagues tried to see whether the fungus Aschochyta imperfecta was killed, but unfortunately the seed died before the fungus. It is a line which should be followed up and might give better results.

Q. Dr. A. G. Fisken

In official Seed Testing Station reports on germination capacity of cereal seeds a figure is given for abnormality. Would it be possible for these Stations to predict, at the time of reporting, the likely effect on ultimate yield of the varying types of abnormality?

A. Dr. M. Noble

The question of abnormality, I think, is judged in cereals by whether the seedling is likely or not to give a good plant, a normal plant, in favourable soil conditions, i.e. for untreated seed. It is asking a tremendous lot to predict at the time of reporting the effect of abnormality on ultimate yield. One even may not know whether the seed has been treated. This may be possible in the future because of the increasing practice of labelling treated seed. This is the kind of information which I feel is going to come from the Seed Pathology Sections of the Seed Testing Stations. The straight germination figure must still be the maximum figure but must be supplemented by a statement, e.g. "This treatment may lead to abnormality in certain soils." I think information will come forward from seed pathology people and from advisory people who can give a tremendous amount of help.

Comment from Mr. H. C. Mellor on Dr. Noble's reference to the term "dressing":

We have had a most interesting session of papers this morning on seed dressings and I should particularly like to make mention of Dr. Noble's reference to the term "dressing" because I remember in the 1930's a series of advertisements relating to seed treatment which read "it pays to be properly dressed". We take Dr. Noble's point.

Q. Mr. H. C. Mellor

I should like to ask Mr. Way if I misheard his reference to the use of 3 oz per bushel of chlorinated hydrocarbons - was this in terms of active agent or of product?

A. Mr M. J. Way

The reference was to active ingredient per acre. Against onion fly, 3 oz on 6 lb of seed per acre, and against wheat bulb fly my rough estimate was 3 oz active ingredient on 150 lb of seed per acre. With seed dressings it would seem to be more useful to define dosage as amount per seed rather than amount per acre or per unit weight of seed.

Q. Mr. H. C. Mellor

In referring to the apparent unnecessary use of dual purpose seed dressings, one must take into account the not inconsiderable insurance value of the treatments. Also seed merchants who carry out most of the treatment must treat well in advance of the season to meet the demand. Could Mr. Way define the infestation level above which the treatment is necessary and if so who is to advise the farmer?

A. Mr. M. J. Way

My reason for referring to "unnecessary" use of seed dressings was because most of the insecticidal seed dressings are used on cereals against wireworms which nowadays are generally scarce in arable land and relatively uncommon even in grassland. Therefore, where the insecticidal component of seed dressings is aimed entirely at wireworms I would suggest that its use in most instances is unnecessary. It is difficult to say when treatment is necessary without a previous assessment of wireworms. I appreciate the argument that, without such assessment, seed dressing of cereals as an insurance against wireworms may still be felt to be justified even though a very small proportion of crops would benefit.

Comment from Dr. G. H. L. Dicker on Mr. Way's contribution:

The use of systemics, applied either to the soil or to the trunks of fruit trees has received study, but the practical application of this method is limited by the present need for foliar applications of fungicides. A plea was made for the Agricultural Chemical Industry to find suitable systemic fungicides for use on fruit.

Observation to Dr. M. Noble from Dr. W. Ripper

With reference to the suggestion that fungicide application to the seeds for the protection against soil borne diseases other than on the seed were desirable, the American practice of applying fungicides such as captan simultaneously with sowing either through seed box or special applicators is worth noting.

Q. Dr. L. Broadbent

Is phytotoxicity assessed by germinating treated seeds in Petri dishes?

Recent tests showed that tomato seeds often failed to germinate after soaking in a solution of tri-sodium orthophosphate to inhibit tomato mosaic virus, whereas germination was not affected in soil.

A. Dr. M. Noble

This is a point which has been very carefully investigated by Seed Testing Stations. It is legitimate to do a germination test in a "blotter" which could be flat with a cover or on a rolled paper towel. I think I am right in saying that especially when BHC was introduced first, seeds treated with this chemical had to be specially tested in soil to avoid undue abnormality. Tests are conducted taking these points into account.

Q. Dr. F. Raw

Mr. Mellor has questioned Mr. Way's use of the word "unnecessary" (NOTE: The printed version of Mr. Way's paper "unwarranted" is used but "unnecessary" was used in the spoken version) when speaking of the widespread practice of making routine applications of insecticidal seed dressings regardless of pest incidence and I wish to ask Mr. Mellor a related question. Passing reference has been made to the high proportion of potato fields treated with aldrinised fertiliser although the proportion of such fields which have a significant pest population is very low (about 5%). Does Mr. Mellor consider such widespread routine use of aldrinised fertiliser "necessary" or "justifiable" and, if not, what should be done about it?

A. Mr. H. C. Mellor

I'm sorry I have no personal experience with aldrinised fertilisers as my Company does not sell them. I think the problem must be looked at from the point of view of the farmer who must judge by the experience on his farm in preceding years. If he has had severe trouble in previous seasons, he can perhaps be forgiven for using such products as an insurance factor.

Observation from Mr. Way

What is unfortunate is that the extensive use of certain insecticidal seed dressings on cereals has been largely responsible for problems of bird poisoning. Otherwise seed dressings would have been an ideal method of insurance.

Observation from Mr. Womack

Mr. Way says that most dual purpose seed dressings are used for control of wireworm. My experience is that there is sometimes an increase in yields even where the wireworm population is low. There are other pests in the soil which are controlled to a certain extent and this factor must be taken into account.

Q. Mr. J. S. W. Simonds

You suggested that the insecticide portion of the seed dressing is probably unnecessary to the now apparent low level of wireworm popula-

tion. Can we balance the potential and presumably low damage to cereals from a low level of attack with the infinitesimal cost of the insecticidal portion of the seed dressing to the farmer. Surely this is an excellent form of insurance inasmuch as one willingly pays fire insurance premiums on one's own property?

A. Mr. M.J. Way

Fire insurance does not have undesirable side-effects whereas with insecticidal seed dressing on cereals you have got to consider the benefits of a cheap insecticidal insurance policy in relation to the harm that some of the insecticides may cause to birds. I appreciate Mr. Womack's point about additional beneficial effects of seed dressings. These may be important and a great deal more research needs to be done on them.

Comments by D.W. Wright

At the N.V.R.S., we have been working for a number of years on the use and behaviour of insecticides in soils. This has shown that some of the chlorinated hydrocarbon insecticides are extremely persistent there. With regard to the unnecessary use of insecticides it would seem that aldrin mixed with fertiliser is now very extensively used in soil, in most cases as an insurance against wireworm damage. On many fields its use in this way appears to have been quite unnecessary, since the pest was either absent or present in numbers too low to cause crop damage. Repeated use of insecticides in this way is liable to lead to a build-up of residues in the soil and these may be harmful. They can be taken up into crop plants and when present at fairly high levels may adversely affect crop flavour. In addition, high residue levels of certain insecticides in the soil have been shown to increase the damage caused by the cabbage root fly through, we believe the killing of predatory insects.

Q. Mr. T.E.T. Trought

Does Dr. Noble consider that work on the effect and methods of seed treatment of grass mixtures is justified?

A. Dr. M. Noble

Yes, certainly in the case of ryegrass. There are fungi on ryegrass especially pedigree strains which might be controlled with mercurials. Timothy Grass will certainly repay treatment but more work is necessary to find out what are the common seed-borne diseases and their reactions. More and more seeds will, I believe, prove to be benefitted by such treatment.

Q. Mr. L.E.W. Stone

There appears to be a schism between the findings of N.V.R.S. on the one hand and the firm's findings on the other concerning the production of taint (off flavour) by aldrin to potatoes.

A. Mr. D.W. Wright

There would seem to be some misunderstanding here, for we have

never found aldrin to cause taint in potatoes. With carrots, however, both aldrin and dieldrin can cause change in flavour. At low dosage rates in the soil, little or no effect has been recorded but at higher rates both insecticides may cause the carrots to take on a distinct chemical flavour.

The effect of lindane on crop flavour is much greater, and when grown in soils treated at $\frac{3}{4}$ lb per acre both carrots and potatoes showed a musty off-flavour ('tainting') in the years immediately following treatment and loss of crop flavour where the insecticide had been in the soil for several years.

Comment from Mr. Billitt to Mr. D. W. Wright, Chairman of Session.

You did make reference, Mr. Chairman, to the uptake by the plant of some of the chlorinated hydrocarbons. We do know that certain chlorinated hydrocarbons are very toxic to birds. There is need for more work particularly on residues on cereals and other crops that are fed to poultry in particular. Avian toxicity particularly low in proportion to mammalian toxicity and it would be advisable for all concerned to look very carefully at the residues in feeding stuffs and then we shall be making real progress.

SYSTEMIC INSECTICIDES INCLUDING THEIR USE FOR VIRUS CONTROL

Chairman: F. C. Bawden
Rothamsted Experimental Station

SYSTEMIC INSECTICIDES AND VIRUS CONTROL IN POTATOES

by L. Broadbent
Glasshouse Crops Research Institute
and P. E. Burt
Rothamsted Experimental Station

Some of the best districts producing table-stock or ware potatoes are those where aphids are numerous and where aphid-transmitted viruses spread readily. Infected plants yield little, so the potato stocks have to be renewed annually, or every few years, with stocks from other districts where aphids are few.

Buying new seed tubers is expensive, particularly when the ware area is distant from seed-growing areas; even in England, which is near two of the best seed-producing areas, Scotland and Ireland, the cost of new seed tubers may account for one-third of the total cost of growing a ware crop. The spraying experiments and farm trials, organized from Rothamsted during the last 14 years, had the aim of prolonging the useful life of potato stocks in England.

Preventing the spread of virus by killing insect vectors is a rather different problem from preventing the plants being damaged directly by insect pests; the epidemiology of the diseases concerned must be considered before the experimental results can be understood. Similarly, differences in epidemiology must be allowed for before attempting to apply insecticide control in areas other than England.

Virus Spread

The two viruses, leaf roll and potato Y, that cause potato stocks to degenerate rapidly in England are both aphid-transmitted. The ways in which aphids transmit the viruses are important in relation to insecticidal control. Aphids can pick up virus Y in a few seconds and transmit it immediately to healthy plants on which they feed briefly. In contrast they must not only feed much longer to acquire leaf roll virus, but they also take a day or more to become infective after they have acquired the virus. Most residual insecticides fail to incapacitate aphids in less than an hour, and therefore do not completely prevent the spread of virus Y, whereas they have up to a day to kill vectors of leaf roll virus before they become infective. There is some decrease in the spread of Y because the insecticides greatly decrease the numbers of aphids, but to prevent its spread, a persistent insecticide is needed which incapacitates aphids so rapidly that

they do not move away from a treated plant.

Of the several species of aphids infesting potatoes in England, Myzus persicae (Sulz.) is the most important vector of viruses; although numerically many fewer, the winged individuals spread virus much more than do the wingless bulk of the population. M. persicae has a very wide host range and usually overwinters in England as living insects both in the open and under shelter. It is, therefore, usually able to infest potato plants as soon as these emerge above ground in late spring. The numbers that reach potatoes depend on the weather and the activity of aphid predators and parasites. The aphids will have come from hosts other than potato, and because no overwintering alternate hosts of potato viruses are known in Britain, the aphids will usually be uninfective when they arrive.

Seed certification schemes ensure that most potato stocks planted for the first time in ware-growing areas contain few infected tubers, but these are scattered in the crop and virus is spread from them to nearby plants by the colonizing winged aphids, usually early in the season. Potatoes are most susceptible to infection when young, and the leaf roll virus is also most readily acquired by aphids from the diseased plants early in the season. Consequently, most spread of viruses usually occurs during May and June. The extent of virus spread depends on the number of infected source plants and the number and activity of the aphids, but the number of diseased plants seldom increases more than ten-fold in one season and stocks of many varieties can usually be kept safely for two years without any measures to check the spread of virus diseases.

Aphids usually leave potato plants as these begin to mature, during July and August, and some of the insects that have been feeding on diseased plants may alight on and infect plants in other potato crops, ofetn infecting initially healthy stocks. Usually fewer than 1% of plants in a previously healthy crop are infected in this way, but occasionally many aphids may arrive from a badly infected crop and infect as many as 80% of plants. Aphids retain virus Y for a few hours at most, but those carrying leaf roll virus may remain infective for the remainder of their lives, so leaf roll is more likely to be carried long distances from crop to crop, and the relatively poor control of Y is less important than it at first appears to be. There is little or no spread late in the season from plants already infected to others within the same crop.

Effectiveness of Different Insecticides

Experiments (Broadbent et al, 1960) have shown that no insecticide, contact or systemic, acts quickly enough to prevent aphids that are already infective when they arrive in a crop from infecting some of the plants they first feed on; therefore it is useless to try to prevent infected aphids bringing viruses into healthy stocks by spraying the plants with insecticides in midsummer; at best, using quick-acting insecticides, the number of infected plants may be decreased slightly. A much more effective way of preventing the infection of healthy stocks is to spray all crops containing infected plants once or twice before the aphids leave them, so

destroying the infective aphids at their source.

Any effective aphicide, contact or systemic, that prevents aphids from colonizing the plants, kills non-viruliferous insects before they can become infective with leaf roll virus, and prevents the spread of this virus within the crop. (Broadbent et al. 1956, 1958) Although no insecticide acts quickly enough to prevent the spread of virus Y, treatment of crops usually decreases this by 50-75% because the aphids are incapacitated before they can visit as many plants as unaffected aphids.

To prevent spread between plants within a crop the insecticides have to be applied as soon as the plants emerge through the ground, and as a practical compromise it is recommended that the first spray should be applied when about 80% of the plants have emerged. The plants are then growing rapidly and a second spray should be applied about ten days later, followed by two more at intervals of two weeks. Thus the plants are protected for about the first two months of growth, during which time most spread occurs.

Most of the experiments have been made with DDT, which is effective when spraying is done with overhead and underleaf lances and is begun before aphids start to colonize the plants. It tends to be less effective in hot than cool weather and fails to kill all the aphids on newly produced shoots or on mature leaves when spraying is by overhead lances only. When a mature crop is being sprayed for the first time, even if underleaf lances are used, it takes a long time to kill all the aphids with DDT. Therefore the first spray at least should be with a systemic insecticide, such as demeton-methyl, phorate or dimethoate, and such insecticides should be used also for any single spray to clear the plants of aphids in midsummer.

The removal of infected plants (roguing) does not decrease disease incidence in unsprayed crops in ware-growing areas because much spread of virus, specially leaf roll, usually happens before symptoms are recognizable. When virus spread is limited by spraying, roguing has enabled stocks to be kept even longer than by spraying alone. Roguing a large ware area is an arduous task, however, and growers may prefer to spray and rogue a small area grown specially for seed, although this is slightly more costly than saving seed from the ware crop.

Recent Work with Systemic Insecticides

Stocks of potatoes have been kept with a low incidence of disease in many parts of England for three to five years when sprayed (Broadbent et al. 1960) some with and some without roguing, and a stock of early potatoes was kept productive for eight years in Hampshire. Although detailed costing (Broadbent et al. 1957) has shown that home-produced seed costs much less than 'imported' seed in most years, and with early varieties has the additional economic advantage of producing an earlier crop, few growers have yet adopted the method because they find spraying four times irksome and difficult in wet or windy weather. The passage of machinery applying the later sprays also damages the plants, but the loss

of yield so caused is sometimes balanced by an increase in yield because spraying prevents damage by feeding aphids and other insects (Broadbent et al. 1958).

In an attempt to lessen the work and damage by tractor-drawn sprayers, experiments are being done with systemic insecticides applied either to the tubers or in the drills at the time the tubers are planted (Burt et al 1960). Preliminary work has shown that menazon sprayed on the tubers, and dimethoate, phorate or thiodemeton distributed in the drills, are absorbed through the roots and pass into the foliage and may prevent aphid colonization for most of the growing season. In an experiment with early potatoes in Hampshire this year, for instance, the numbers of wingless potato aphids on 100 leaves on 8 June, twelve weeks after planting were

	Total	M. persicae
Untreated	930	418
dimethoate ($4\frac{1}{2}$ lb/acre	99	63
menazon (1.3 lb/acre or 0.8 lb/ton seed)	49	26
phorate ($4\frac{1}{2}$ lb/acre)	0	0
thiodemeton (1 lb/acre)	0	0

(all rates are for active ingredients)

In two previous experiments dimethoate gave as good control as other compounds and in 1960, when applied to the drills at planting at 4 lb per acre, it checked aphids and virus spread better than DDT sprayed five times at 2 lb per acre per application. Some of the systemic insecticides delayed emergence, but when applied at rates just sufficient to control aphids, they depressed yields only slightly.

Further work needs to be done before these methods can be recommended to growers. Optimum rates of application must be determined and, although toxic residues in the tubers when the insecticides are applied at normal rates are very small, experience in a wider range of conditions may be required before tubers from treated crops can be sold for eating. The worst risk to consumers would probably arise from accidental overdosing by growers, and it is desirable, therefore, that ware crops should be treated with those compounds least toxic to mammals. In crops grown specially for seed the residue problem does not arise.

It will also be necessary to find out how soon soil-applied insecticides enter the leaves, for preliminary tests showed that aphids may not be killed during the first week after the shoots emerge. This will not matter with early potatoes because they usually emerge before aphids are flying, but it may be necessary to spray main crops once when they emerge during May.

We, and our colleague G. D. Heathcote, are now working on other problems, and our last potato experiment will be done in 1962. Perhaps N. A. A. S. Officers and the firms marketing the insecticides will continue the work and persuade growers that it will pay them to control virus diseases so that they can retain their stocks of potatoes for a year or two longer than is now customary.

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CONTROL OF SUGAR-BEET YELLOWS

by R. Hull

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The grower wants to produce as much sugar per acre as possible, as cheaply as possible. These truisms should be kept in mind when considering the control of virus yellows in sugar beet crops. The objective is the control of yellows in so far as it gives an economic increase in sugar yield.

Three features of the disease are important in relation to control by systemic insecticides. First, the disease is spread mainly by Myzus persicae; secondly, the prevalence of virus sources in spring greatly influences the incidence of the disease; thirdly, the earlier a plant is infected during its growth, the less sugar it produces. Let us examine these three points, vectors, virus sources and yield losses, in more detail.

The importance of M. persicae as a vector of yellows has been demonstrated in several ways. Controlled experiments show its greater efficiency than other species of aphids in transmitting the virus. From data collected in field surveys over nine years, Watson and Healey (1951, 1953) showed that the incidence of yellows was directly related to trap catches of winged M. persicae. Surveys made each year by the British Sugar Corporation since 1946 clearly show that yellows is severe when green aphids are numerous and early on sugar beet, and that the incidence of yellows is not related to the prevalence of black aphids. When sugar beet in the field are examined in May and early June, occasional green aphids of several species are found on them. These may be important field vectors but M. persicae usually soon outnumber them, and as their numbers during the early stages of infestation of sugar beet are probably correlated with those of M. persicae, a comprehensive count of green aphids seems a good guide to the prevalence of M. persicae. Undoubtedly exceptions occur, as for instance when sugar beet are heavily infested in May with Myzus ascalonicus or with Macrosiphum enphorbieae. Such infestations are not necessarily followed by yellows.

We do not know whether the vagrant winged aphids of the many species that visit sugar beet, but do not start colonies on it, are ever important as vectors. They may spread yellows in those fields or districts, encountered occasionally, where yellows becomes severe although green aphids on the plants were always few. In general, however, the appearance and increase of M. persicae on sugar beet is a reliable indication that yellows will follow.

Yellows virus persists in aphids for only a matter of hours, so the M. persicae which infect sugar beet must have fed on yellows-infected plants a short time before. Some potential sources of viruliferous aphids are obvious, for the plants can be seen to have yellows and winged M. persicae; for instance, seed crops of beet and mangold, garden crops

of seakale beet, ground-keeping plants of all cultivated Beta species, wild beet in coastal districts, the sprouts of clamped mangolds and red beet. Some of these are of local importance only. Measures have been taken to deal with others such as seed crops. Aphid-infested mangold clamps are important because they are ubiquitous and a potent source of winged viruliferous aphids over a long period in the spring. A practical method of dealing with them is much needed.

The role of weeds as virus sources needs further investigation. For several years we have placed aphids collected in April and May from weeds growing near beet fields on to sugar beet in the glasshouse. Occasionally mild and ephemeral yellowing develops on the beet. The only aphids which produce symptoms of sugar beet yellows virus are those from Beta species - e.g. stecklings, groundkeepers, mangold shoots. Are the mild yellowings of any importance? Does the sugar beet mild yellows virus (SBMYV) which Russell (1958) has shown to be so prevalent in English beet crops, originate from weeds?

The obvious spread of yellows to crops surrounding a source of viruliferous aphids will give a clear impression of its local importance, but may give a false impression of its direct importance to crops further afield. The deposition of aphids will be inversely proportional to at least the square of the distance if not the cube or a higher power. Thus aphids moving directly from a source to a crop more than a mile or so away are unlikely to infect more than an occasional plant per acre.

In some years, especially after a hard winter, most M. persicae found on beet during early summer occur on the few plants with yellows, and most of the crop is uninfested. M. persicae thrive and multiply better on plants with yellows than on uninfected plants, and they produce more alatae. (Baker, 1960) The aphids on such plants are probably the progeny of the winged aphid that infected the plant. They spread the virus to neighbouring plants and the winged aphids they produce will infect plants still further afield. I give this explanation of the course of development of yellows outbreaks so often seen - occasional infected plants in June, patches in July and an explosive development throughout the whole crop in August. This, though, is not invariable. Sometimes the crop can become yellow rapidly in June and July. The concentration of aphids on plants with yellows suggests that most of the winged aphids arriving early in the crop carry yellows virus, and these infect the plants and start the colonies. Field observations suggest that their likely source, after a hard winter, is clamped mangolds. An alternative explanation is that M. persicae not carrying yellows virus are seldom able to establish colonies on healthy sugar beet, which is supported by glasshouse experience; a third explanation is that sugar beet with yellows attract more aphids.

Eliminating the spring sources of virus and aphids will avoid early 'blanket' infection of neighbouring young root crops, but will never be so effectively accomplished as to prevent all infections. So long as a few plants get infected in young root crops, severe outbreaks may develop during favourable springs and summers, unless spread in the root crop can be otherwise controlled.

Experiments in the 1950's (Hull, 1960) established that the loss of sugar yield is proportional to the period, within the limits of infection times in the field, during which a plant has yellows. About $4\frac{1}{2}\%$ of the potential sugar yield is lost for each week a plant shows yellows symptoms up to the middle of October. Thus plants with yellows at the end of June lose 60%, July 45%, August 27%, and at the end of September 9% of their sugar yield.

These losses apply to April-sown beet infected with a virulent strain of sugar beet yellows virus. They do not necessarily apply to infection with other strains or mixtures of viruses which are common in the field. Nevertheless, the total loss caused by the disease in Great Britain calculated from this figure agrees reasonably well with the loss calculated by other methods. (Hull, 1959).

Plants in the field develop yellows at different times so the experimenter is faced with the problem of getting a single figure for assessing the efficacy of his treatments. The count of infected plants at the end of August includes all those suffering the worst yield depression; a calculation of the 'infected plant weeks' from a series of counts at monthly intervals gives a figure proportional to the yield loss. The best assessment, although the most laborious, is to determine yields. Insecticide treatments may have other effects than controlling yellows; for instance, the direct feeding damage of vectors may be controlled; and infections caused by many vectors may have a different effect on yield from those caused by few.

Spraying with systemic insecticides has proved useful, in conjunction with other measures, for controlling yellows in stecklings. In stecklings, prevention of infection is essential; delaying infection is not enough. Viruliferous alate aphids invading stecklings in August and September will infect them with yellows even if they are sprayed at weekly intervals. Other measures, such as isolation or sowing under cover crops, must be taken to protect the stecklings while winged aphids are numerous.

The risk of direct infection by winged aphids usually decreases later in the year; late-sown stecklings have fewer plants with yellows than early sown ones, but do not grow big enough to transplant. Seed crops might, however, be sown in late August or September to grow on in situ. An improved method of seed growing may come from late sowing combined with protecting the seedlings against aphids, right from emergence, by seed or soil treatment with systemic insecticides.

Systemic insecticides have proved of immense value in controlling yellows in root crops. Field experiments show that a spray gives a worthwhile yield increase in crops where more than 20% of unsprayed plants develop yellows by the end of August. The more severe the yellows attack, the greater the increase in yield from spraying. On average, an early spray increases yield more than a late one and two sprays are only slightly better than one. But the best time to spray differs greatly in different seasons and districts. When aphids arrive early, an early spray is essential, and a late one may be useless. Conversely, when aphids are

late, an early spray may be useless. When aphid infestation persists, two or even more sprays may be economically worth while. Experience shows that sprays at high gallonage are better than those at low, and that spraying is ineffective in windy, hot sunny weather.

The average increase in sugar yield from spraying is about 12%, but increases of 30-40% are common and the record is over 100%. Because the time of spraying is important, growers need to know when to spray. Following discussions by the Virus Sub-Committee of the International Institute of Sugar Beet Research, spray-warning schemes suited to their own circumstances were arranged in France, Belgium, Holland, Germany and Great Britain, and information on the development of aphids and issue of spray warnings are exchanged between the countries.

In England we try to assess in March the probable need for spraying from observations of aphids on winter hosts. A summary of the information collected is sent in bulletins to the British Sugar Corporation agricultural staff, to the National Agricultural Advisory Service and others. Spray warnings are sent to beet growers by the sugar factories when daily counts of aphids on sugar beet, made by the British Sugar Corporation fieldmen, indicate that green aphids are clearly beginning to multiply. Individual growers, all those in a fieldman's area or all in a factory's area, may be sent warnings according to the pattern of aphid infestation detected by the fieldmen's counts. An arbitrary figure of 0.25 aphids per plant is taken as the danger point, but other factors are taken into account, such as, the proneness of a district to get yellows, the incidence of yellows the previous year, the prevalence of virus sources, the suitability of the weather for spraying and for aphid development, the rate at which aphids are increasing, and the stage of development of the crop. More factual information is required to relate the fieldmen's aphid counts to the optimum time to spray, and we propose to experiment to this end.

In each of the five years the spray warning scheme has been in operation, we have had conditions favouring aphids and yellows in the spring, and spray warnings have been sent to growers in most beet growing areas. The acreage sprayed has been considerable - 100,000 in 1957 and 1958; 180,000 in 1959; 220,000 in 1960; and 330,000 in 1961. Some growers are still reluctant to spray solely because of the reported presence of a few green aphids which they cannot find, but are quite happy to do so when they see an infestation of black aphids. Time and experience will doubtless improve the warning scheme and also make growers understand the need to take early action.

The scheme has been adversely criticised on two counts, which are mutually contradictory. One criticism is that infestation varies so much from field to field that growers are being advised to spray fields where there are no aphids to kill; the other is that the scheme is attempting to be too refined and that growers should simply be advised to put on three sprays at fortnightly intervals each year as a routine.

I think it is wise to take the intermediate course. We are aiming to control yellows, not aphids, as pests. To control yellows the develop-

ment of M. persicae infestation must be anticipated - hence spraying is advised when the infestation clearly begins to build up on sugar beet. As past experience shows that, when conditions favour spread of yellows, most fields in the affected area suffer, all farmers should be advised to spray whether or not their field is infested at the time. The weather may turn against aphids after the spray warning, and little yellows develop in crops whether sprayed or not - an inevitable risk until the weather the coming month can be predicted. The threat that yellows would be severe in each of the last five springs has encouraged the idea of routine spraying. Of the ten pre-spraying years, 1947-1956, in only two were more than 100,000 acres with over 20 percent of plants infected at the end of August (the criterion of whether spraying is justified); in five fewer than 35,000 acres would have responded to a spray. As well as this seasonal variation in incidence, the geographical distribution of yellows differ each year. A few areas get yellows almost every year and sensible growers in them spray as a routine. Since 1950, sugar beet have been infested late with green aphids in six years, early in five, and very early in one. When, therefore, should routine spraying start? The early infestations were 1952 and the five years 1957-1961 - perhaps we are due for some years of late infestation, and if routine spraying were recommended in all areas, growers would soon tire of spraying to no effect. We must not destroy predators and parasites or hasten the selection of spray-resistant aphids by unnecessary spraying. For these reasons growers should be told when to spray each year.

Each year has confirmed that spraying at the time of the warning has increased yield. Comparison of sprayed and unsprayed crop shows that spraying halves the incidence of yellows on average. The incidence of yellows in unsprayed fields has probably also been decreased by spraying such a large proportion of the acreage (up to 95%) in some areas. Evidence of this effect comes from the early spraying experiments when the unsprayed plots on the outside of the experiments had more plants with yellows than the unsprayed plots surrounded by sprayed ones. I think we can justifiably claim that spraying, with the other technical developments, is responsible for the record yields which have recently followed each other year by year.

The serious incidence of yellows in 1961 has raised doubts in some minds about the efficacy of spraying. In other years, such as 1957, when yellows has been severe, all plants on the sprayed plots have had yellows by September, but spraying has nevertheless increased yield by delaying infection. If the estimated yield this year is actually achieved it will be the second best ever obtained; without spraying yellows would have been of record severity and the yield would have been very much lower.

One striking feature this year is the frequency with which the incidence of yellows may be slight, say, 5 percent, in one field, and 100 percent in a neighbouring field, even when both have been sprayed. This erratic distribution has often been seen before the days of spraying, years when yellows incidence was moderate. Factors such as sowing date, plant population, soil fertility, variety and soil type, can greatly influence

yellows incidence when it is 'marginal'; spraying changed 1961 from a 'severe' to a 'marginal' yellows year. The low yellows incidence crops are those sown early, well grown, with a high plant population.

Developments in seed dressing, granular formulations and soil treatments with systemic insecticides, will no doubt influence the nature of future control measures. Seed treatments are an attractive, easy control measure, but their effects do not usually persist long enough to replace the control now obtained by spraying. If, however, the sugar beet crop itself is an important source of the viruliferous winged aphids, seed treatment, or an early soil treatment may kill the few aphids that come from the winter sources and initiate colonies on the sugar beet crop.

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COMPARISONS OF APHICIDES, ESPECIALLY GRANULAR SYSTEMICS, FOR CONTROL OF BEET YELLOWS

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In the years 1954 to 1959 Hull (1960) tested the timing of demeton-methyl sprays to control aphids and yellows and assessed the yield response. Since 1957, on average, 227,000 acres of sugar beet have been sprayed annually to control both direct damage by aphids and especially the spread of yellows, the insecticides most used being demeton-methyl, dimethoate, fluoroacetamide and phosphamidon. (Dunning, 1961). These and other commercial and experimental aphicides have been compared in field trials since 1957 and in the glasshouse in 1960 (Dunning, 1959; Dunning and Winder, 1960, 1961).

Seed dressing formulations of systemic insecticides, such as phorate and thiodemeton, have been tested since 1957. Carbon-based seed-dressings of phorate and thiodemeton gave some control of aphids and yellows but were almost always phytotoxic (Dunning, 1960; Dunning and Winder, 1961).

In 1958 granular formulations of phorate and thiodemeton were tested in the field as soil treatments and later as foliage treatments, a technique reported to give good control of Myzus persicae in April/May applications on fall-planted sugar beet in California (Reynolds et al., 1960). The dosage, phytotoxicity, methods and timing of application of phorate and thiodemeton granules have been tested for several years, and the effects compared with demeton-methyl sprays. These results will be reported elsewhere. In this paper experiments made in 1961 are described which tested the size and concentration of granules, their placement by machine, and compared their effect with the same amount of insecticide applied as a spray.

Aphid control was assessed where possible but more attention was given to assessing yellows incidence and especially the effect of the treatments on yield. The number of aphids per plant at a particular time were averaged for the treatment from counts of all aphids on a random sample of plants in each plot. Yellows incidence was obtained at intervals during the season by rapid visual assessment on as many plants as possible; these results have been converted into infected-plant-week totals* and then expressed as a percentage decrease in incidence of yellows for each treatment. Yield was determined by lifting suitable samples, topping, washing, weighing, determining sugar percentage by polarimeter, and hence sugar yield per acre.

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* $4\frac{1}{2}$% of this total gives the calculated percentage loss of potential yield (Watson, et al., 1946).

Granule Placement

The first trials with granules tested them either broadcast and harrowed into the seedbed immediately before drilling, or drilled mixed with the seed.

Broadcasting the granules entailed using 2-3 lb of insecticide per acre but was reasonably effective in controlling yellows and increasing yield (Dunning, 1960); drilling the granules with the seed produced intolerable phytotoxicity at dosages which controlled aphids; increased granule size decreased phytotoxicity (Dunning and Winder, 1961). An extensive trial in 1959 with an experimental placement drill showed that granular demeton-methyl, dimefox, dimethoate, phorate and thiodemeton were non-phytotoxic at rates of up to 4 lb active ingredient when placed 2" to one side of the seed and slightly deeper; when placed in the row with the seed they caused damage unless used at 1 lb active ingredient per acre or less. The single-row plots, 30' long, did not permit satisfactory aphid counts, but seven weeks after drilling on 1 May the side-placed treatments had an aphid infestation similar to that of the equivalent in-row treatments which suggests that side placement should be an effective, as well as non-phytotoxic, method to test in further trials. Dimefox gave the best control of aphids, followed by thiodemeton, but differences in the effect of the insecticides were small.

In 1961 different amounts of thiodemeton granules were side-placed into the soil with a 'Gandy' granule applicator fitted with special coulters, either at the time of drilling or of steerage hoeing. These treatments were compared with a demeton-methyl spray, and with thiodemeton granules applied, by the 'Gandy' mounted on the steerage hoe, onto the foliage so that some of the granules were retained on the plant and the remainder fell onto the soil in a 4' band. The trial was at Dunholme on limestone soil, plot size being 8 rows x 52' (1/66 acre) with 4 replications of 6 treatments (Table 1, Figures 1 and 2).

The 32 oz rate of thiodemeton, side-placed at drilling time on 15 April, gave poorer aphid and yellows control but much better yield increase than the 8 oz rate. Results for the two rates have been averaged in Figures 1 and 2. The thiodemeton foliar top-dressing at 16 oz active ingredient per acre and the demeton-methyl spray, applied on 6 and 7 June respectively, gave rapid aphid control. The former was the more persistent and gave considerably greater yellows decrease and the only significant sugar yield increase. Thiodemeton granules side-placed into the soil at the same rate and time acted more slowly but gave the most persistent aphicidal action and nearly equalled the demeton-methyl spray in yellows decrease and sugar yield increase. Only 1.3" rain fell between the drilling treatments on 15 April and the remaining treatments on 6-7 June, but 0.6" fell during the following week. Maximum temperature on 6-7 June was 72° F.

Granule Size and Concentration of Active Ingredient

Foliar top-dressings with granules of different sizes and concentrations were compared in a field trial on limestone soil at Dunholme. The

various thiodemeton and 0.5oz* menazon granule formulations were all applied at 16 oz active ingredient per acre. They were distributed, from hand-shaken perforated tins, in dry breezy air conditions and a temperature of 75°F. on 16 June. An experimental product, CR5331, at the same 16 oz rate and a demeton-methyl spray at the standard 7 oz rate were also tested. The plants averaged 8½" diameter. The nine treatments were replicated four times on plots 30' x 8 rows (1/115 acre) (Table 2).

All treatments except menazon controlled black and green aphids within three to four days. Subsequently black aphid numbers were variable, but CR5331 clearly gave the best kill and persistence. In the control of green aphids, mainly M. persicae, menazon was again inferior to demeton-methyl spray. The large sized 5% thiodemeton granules (formulation 4909a) gave inferior aphid and yellows control and increased yield less than the normal-sized 5% granules (formulation 4909).

In the case of concentration comparison, 10% thiodemeton was superior to the 5% and 2.5% formulations in aphid control and yellows decrease, but inferior in yield increase. The higher concentration granules could not be applied as uniformly as the lower concentrations. The CR5331 granules controlled yellows well and gave the highest and the only significant yield increase.

Foliar Application Rates of Granules and Sprays

The efficacy of granules applied to the foliage may well be due to the high application rate per acre adopted and this was tested in a field trial at Broom's Barn Experimental Station, near Bury St. Edmunds. The sprays were applied on 26 May in a 7" band over the row at 2 oz a.i./acre, and at 24 oz a.i./acre to compare exactly with the granule treatments. Except for menazon (12.5 oz), these were applied at 24 oz a.i./acre to the foliage and adjacent soil in a band of the same width, on the 28 May, using perforated tins. The twelve treatments were replicated four times; plots were 60' x 18 rows (1/24 acre). Application rates of active ingredient per acre are given in Table 3; the 2 oz band-spray rate was the equivalent, on the plants, of an overall spray of 6 oz, approximately the normal commercial rate; in overall spraying with systemics the material falling on the inter-row soil is presumably wasted.

There were few Aphis fabae on 14 June and the counts made have little significance except to show that phorate and thiodemeton granules gave the best control. All treatments, except phorate spray at the 2 oz rate, controlled the more numerous green aphids well; phorate and dimethoate sprays and granules gave excellent control at the 24 oz rate. Menazon granules at 12.5 oz controlled green aphids better than the spray at 2 oz.,

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* The 5.0 % menazon granules proved on analysis to contain only 2.6 oz and, therefore, only 8.3 oz a.i. were actually applied.

but not as well as at 24 oz.* Yellows counts are summarized as infected-plant-week decreases in Table 4, and show treatment effects paralleling the aphid counts. Phorate granules at 24 oz a.i./acre were slightly better than the spray at the same rate.

Each insecticide as a spray at the 24 oz rate gave slightly better sugar yield than the granule formulation. The plants had seven leaves when treated, still rather small for ideal granule retention.

Foliar Top-dressing with Granules by Machine

All trials of foliar top-dressing with granular systemics have been on relatively small plots and, except in Trial I above, the granules were applied from perforated tins shaken by hand. Machine application, when combined with tractor-powered row-crop work, should be more accurate and uniform.

In co-operation with G D. Heathcote, a 5 x 5 latin square trial was made at Broom's Barn comparing time of demeton-methyl spraying with foliar top-dressing of granular phorate. The plots were 70' x 36 rows (1/10 acre). The demeton-methyl was applied by the farm's tractor-drawn sprayer and the 10% phorate granules, at the rate of 13.7 lb (22 oz a.i.) per acre in a 2" band above the row, by a 'Horstine Farmery' granule applicator, mounted on the A share frame behind a tractor carrying the 5-row underslung hoe.

Control plots had 4.1 green aphids per plant on 24 May, 5.2 on 15 June and 9.2 on 29 June. Singling was completed by 25 May, when the plants had six leaves.

Phorate granules controlled yellows better than either the early or late sprays, but less well than the two sprays together. The granules gave the only significant increase in yield. (Table 4). Visual scoring by two independent observers on 1 August showed the phorate treated plots to be slightly greener in general appearance than those that had been sprayed twice.

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* Other trials in 1961 show clearly that the menazon spray formulation, a dispersible powder, used in this trial was much inferior to a liquid formulation with improved wetting properties and smaller particle size.

Discussion

The results of the above and other trials comparing thiodemeton granules applied to the foliage and demeton-methyl sprays are summarized below.

Year	No. of trials	% decrease in infected-plant-week total: Thiodemeton granules (average no. of oz.a.i./acre)	One demeton-methyl spray	Two demeton-methyl sprays
1960	4	57.8 (30.0)	49.4	-
1961	7	51.3 (21.7)	30.2	-
1960-61	11	53.2 (24.7)	36.0	-
1960-61	4	58.4 (26.0)	49.3	61.8

Foliar top-dressing with granular thiodemeton controlled yellows much better than did a demeton-methyl spray, especially in the 1961 trials. Two field trials in 1960 and two in 1961 (not reported in this paper) included two times of spraying with demeton-methyl, which approximately equalled thiodemeton top-dressing in decrease of yellows incidence.

The relative contribution to this result of the small proportion of granules remaining on the plant and the large proportion falling on the soil is unknown, but the former is probably by far the more important and hence the effect of soil type on this method of application is likely to be small. Application to foliage, some falling on the soil, was compared in 1959 with application to the soil surface near the plants; the former gave significantly better control of yellows. The National Institute of Agricultural Engineering tested these two treatments in 1961 and obtained the same result.

Granules are retained well by the rosette of sugar beet foliage provided the plants are large enough; the larger the plant, the greater the proportion of granules retained and the more efficient the control of black and green aphids compared with low or medium volume sprays.

In one 1959 trial thiodemeton applied at 48 oz a.i./acre to the sugar beet foliage gave lighter patches of green on the leaves where granules had lodged in hollows. The 10% thiodemeton granules in Trial II gave the best control of yellows but less yield than three other granule treatments - the 10% granules may have been slightly phytotoxic. Again, in Trial III, phorate and dimethoate granules controlled yellows slightly better than sprays at the same 24 oz rate, yet sprays of both materials gave the greatest yield increase.

Dry plants are preferred for applying granules in California, so that granules do not adhere to the leaf surface (Reynolds, et al., 1960); all our applications were made in dry conditions and almost invariably in temperatures of 60-80° F with some wind. The mode of action is probably fumigant in the first case, especially in still weather and when the plants are

large. Unpublished results of laboratory tests by Fisons Pest Control Limited in 1961 demonstrated the highly toxic nature of the vapour from 5% phorate and thiodemeton granules. Bean plants infested with Megoura viciae were placed in a muslin-covered glass cage together with a dish of granules; phorate and thiodemeton gave complete control of aphids within 24 hours, whilst control was insignificant with the much less volatile materials dimethoate and schradan. Control by phorate and thiodemeton may have been due to fumigant or systemic action since, following 24 hours caging with a disk of granules, the bean plants showed marked residual aphicidal action after removal of the granules.

Granules retained by the plant, mainly in the leaf axils, are probably moistened by dew, and dissolved material is absorbed and translocated in the plant. Contact action is likely to be of minor importance. Menazon has low volatility and solubility, which may explain the comparatively poor results given by the granule formulations in Trials II and III above, although the lower rate of application must also be considered. Dimethoate granules in trial III controlled aphids well and this was most probably by systemic action, being a fairly soluble material.

Further experimentation with foliar top dressing is justified by the good results achieved in 1960-61, especially from the machine application in Trial IV, but the results of Trial III suggests that an equivalent rate of application in spray formulation would give equally good results. Economics and toxic hazards must be considered, also the possibility of beneficial insects being more harmed by sprays than by granules.

Trials in Germany demonstrated the longer aphicidal effect of higher than lower rates of demeton-S-methyl and demeton-S-methyl sulfoxide (800 ml v 400 ml/ha - whether a.i. or formulated product not stated) but did not determine the effects on yellows incidence or yield, (Kolbe, 1960). The effect of a treatment on yellows incidence and subsequent yield is compounded from many factors - not only the speed, completeness, and persistence of aphicidal action, against both green and black aphids as vectors and direct pests, but also disturbance of viruliferous aphids, effects on beneficial insects, and especially the timing of treatment in relation to the period of invasion by viruliferae.

Predators can certainly be an important factor in determining the degree of aphid control achieved by insecticides applied to sugar beet foliage. Placing systemic insecticide in the soil, apart from being fundamentally sound, should give maximum integration of chemical and biological control, the need for which has been stressed by many authors, especially Ripper (1957).

Many factors influence the results from soil application, as discussed by Burt et al. (1960), but their trials used very high rates of insecticide formulated with activated carbon. Sylvester et al. (1961) placed thiodemeton (1.03 lb a.i./acre) 7 inches to one side of the row and 5 inches deep, two weeks before foliar top-dressing on 2 April. The former was ineffective for a month in controlling aphids and remained inferior in aphid control and yield increase to the latter. We experimented with much

closer and shallower side-placement, and results in Trial I were quite promising. Side placement can avoid the excessive use of insecticide but may not be as effective as when more uniformly distributed in the soil. However, broadcast application necessitates pre-sowing treatment, whilst timing of side placement is more adaptable.

Side-placement at drilling time is too early for most root crops, although it may be suitable for stecklings. In any case, the mechanical difficulties of attaching soil-placement coulters to precision drills are considerable, especially because the seedbed must not be disturbed. Mounting a granule applicator with soil-placement coulters on a steerage hoe is feasible (Trial 1), and mechanical improvements should enable the granules to be placed in various positions relative to the plant in future trials. The first steerage hoeing is likely to be the most suitable time to apply the materials and the fact that aphicidal action will not be immediate is unimportant (Figs. 1 and 2); soil type and moisture, placement position and physical properties of the material, are likely to affect the results considerably.

Summary

Phorate and thiodemeton are phytotoxic to sugar beet when used as seed dressings; granular formulations of these and other systemics enabled experimentation with soil and foliage application.

Foliar top-dressing by hand or machine gave the best aphid and yellows control, and yield increase, approximately equalling two demeton-methyl sprays. The possible mode of action is discussed. Large granules of thiodemeton were less efficient than small, and granules of high concentration gave better aphid control but poorer yield than low concentration granules. Sprays and granules of both phorate and thiodemeton, all applied to the foliage at the same rate of active ingredient per acre, gave similar results.

Thiodemeton granules side-placed at drilling time controlled aphids poorly, but decreased yellows incidence and increased yield. Side-placement after singling gave delayed, but eventually better, aphid control than did demeton-methyl sprayed at the same time.

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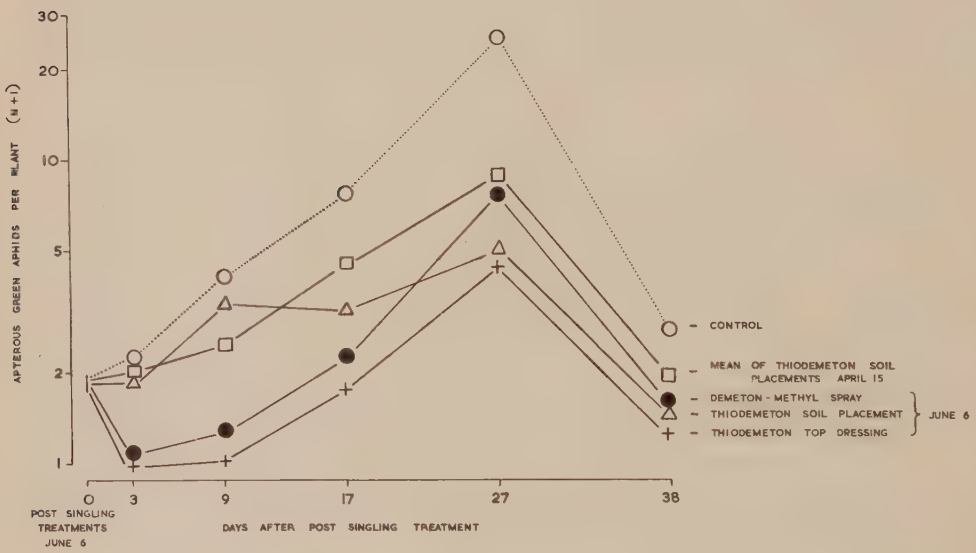

FIG. 1 APTEROUS GREEN APHIDS PER PLANT (N+1) AT INTERVALS AFTER TREATMENT IN TRIAL 1. SEE TABLE 1 FOR FURTHER DETAILS OF TREATMENTS

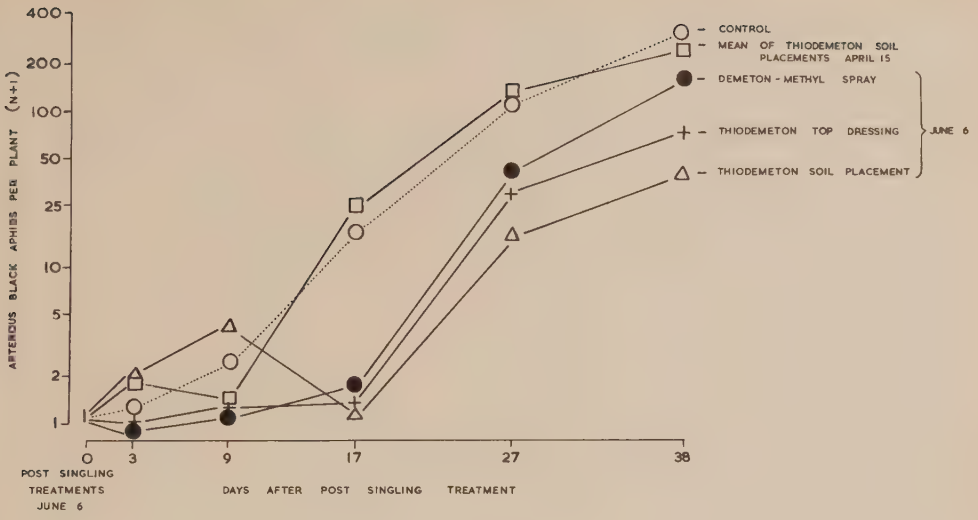

FIG. 2 APTEROUS BLACK APHIDS PER PLANT (N+1) AT INTERVALS AFTER TREATMENT IN TRIAL 1
SEE TABLE 1 FOR FURTHER DETAILS OF TREATMENTS.

Table 1 Comparison of thiodemeton granules (4909b - 2.5%), side placed and top dressed, with demeton methyl spray.

Treatments (oz a.i./acre)	Yellows Incidence.					Yield		
	% Infection (angles)				% decrease in infected-plant week totals	Weight of washed beet (tons/acre)	% Sugar	Weight of sugar (cwts/acre)
	13 July	24 July	16 Aug.	4 Sept.				
Control	11.4	19.1	58.2	62.9	0	12.38	15.1	37.5
Demeton methyl spray on 7 June (7oz in 45 g.p.a.)	7.5	11.3	41.0	54.5	25.2	13.89	15.3	42.4
Thiodemeton placed 4" to one side of seed & 2" deep at drilling time on 15 April (8 oz)	6.5	8.7	40.4	55.4	23.2	12.47	15.4	38.4
" (32 oz)	10.9	16.6	44.5	54.8	20.6	13.94	15.4	43.1
Thiodemeton applied as foliar top dressing on 6 June (16 oz)	6.3	9.4	37.4	45.9	40.7	14.66	15.3	44.8
Thiodemeton placed 4" to one side of singled plants & 1" deep on 6 June (16 oz)	8.9	13.2	42.5	54.3	23.7	13.09	15.5	40.4
S.E. per ± treatment mean.	1.8	2.5	3.5	2.6		0.62	0.2	2.2
L.S.D. (P=0.05)	5.5	7.5	10.5	8.0		1.85	0.6	6.5

(For aphid populations see Figures 1 and 2)

Table 2 Effect on granule size and concentration of active ingredient on aphid numbers, yellows incidence and yield increase.

Treatments (oz a.i./acre)	Numbers of apterous aphids per plant								Yellows Incidence					Yield		
	Black				Green				% Infection (angles)							
	19-20 June	27 June	4 July	18 July	19-20 June	27 June	4 July	18 July	13 July	24 July	17 Aug.	5 Sept.	% decrease in Infected-plant-week totals	Weight of washed beet (tons/acre)	% Sugar	Weight of sugar (cwts/acre)
Control	0.78	9.19	33.78	257.73	3.13	4.94	6.55	0.25	7.8	12.6	43.9	62.0	0	13.37	15.4	41.3
Demeton methyl spray at 40 g.p.a. (7 oz)	0.13	4.19	34.50	220.03	0.15	0.75	2.35	0.15	13.0	15.8	43.7	59.4	1.9	12.79	15.7	40.1
Menazon granules 0.5% (16 oz)	2.33	5.88	92.23	234.50	2.50	2.47	4.85	0.18	4.4	9.5	39.9	55.1	16.5	13.24	15.7	41.7
Menazon granules 5.0% (8.3 oz)	2.13	2.31	40.25	219.05	2.00	1.47	2.55	0.15	8.0	11.9	43.4	60.3	3.5	12.65	15.8	40.1
Thiodemeton granules 4909b - 2.5% (16 oz)	0	1.38	30.03	119.73	0	0.31	1.58	0	6.7	11.3	32.9	47.4	31.9	15.35	16.4	50.1
Thiodemeton granules 4909 - 5% (16 oz)	0.03	1.34	41.48	125.03	0.13	0.34	1.70	0	9.2	10.6	31.5	44.7	37.5	15.43	16.3	50.2
Thiodemeton granules 4909a - 5% (16 oz)	0.20	6.00	36.43	146.88	0.58	0.84	1.73	0.03	5.4	5.5	33.3	52.3	25.7	13.83	16.1	44.6
Thiodemeton granules 5127 - 10% (16 oz)	0	1.66	30.88	104.58	0.03	0.38	0.88	0	4.0	6.0	27.5	44.1	43.0	14.31	16.2	46.3
CR5331 - 5% (16 oz)	0	1.91	24.25	58.20	0.10	0.34	1.05	0.03	3.0	7.8	32.9	44.4	39.0	15.93	16.3	51.8
S.E. per treatment ± mean.									3.1	3.8	4.3	3.8		0.85	0.25	3.24
L.S.D. (P = 0.05)									9.0	11.2	12.6	11.0		2.48	0.7	9.5

7 days before treatment there were 1.63 black and 0.28 green apterous aphids per plant, whilst at the time of spraying on 16 June there were 1.35 black and 3.00 green.

Table 3 Comparison of granule and spray application

Treatment * (oz active ingredient per acre)	Nos. of apterous aphids per plant on 14 June **		Yellows incidence ***				Yield		
	Black	Green	% Yellows (angles)			% decrease in i.p.w.	Weight of washed beet (tons/acre)	% Sugar	Weight of sugar (cwts/acre)
			10 July	1 Aug.	25 Aug.				
Control	1.38	5.19	13.3	54.9	61.2	0	14.89	15.2	45.3
Demeton methyl spray (2 oz)	1.38	0.62	4.9	29.9	48.6	37.3	16.25	15.0	48.6
Phorate spray (2 oz)	2.03	4.97	10.5	48.8	63.9	0.4	14.60	15.0	43.7
Phorate spray (24 oz)	1.00	0.14	3.6	20.5	40.3	55.9	17.42	15.6	54.1
Phorate granules 10% (24 oz)	0.22	0.19	2.7	19.5	38.0	60.3	17.40	15.5	53.8
Thiodemeton granules 5% (24 oz)	0.30	0.05	2.5	14.8	30.0	73.6	17.50	15.6	54.7
Menazon spray (2 oz)	0.86	2.19	4.0	36.6	54.0	24.4	16.28	15.2	49.3
Menazon spray (24 oz)	1.43	0.24	4.3	23.0	42.9	50.5	17.15	15.1	51.7
Menazon granules 5% (12.5 oz)	0.84	0.89	5.6	33.4	51.8	30.0	15.90	15.1	48.0
Dimethoate spray (2 oz)	0.54	1.78	5.2	35.8	55.8	22.3	15.62	15.0	46.7
Dimethoate spray (24 oz)	2.00	0.08	2.3	19.8	37.8	60.1	17.74	15.7	55.6
Dimethoate granules 6.9% (24 oz)	1.19	0.08	3.5	19.2	38.0	60.2	17.22	15.6	53.7
S.E. per treatment mean. ±			1.8	3.9	3.1		0.50	0.21	1.86
L.S.D. (P = 0.05)			5.1	11.3	8.9		1.45	0.6	5.4

* All sprays applied at 20 g.p.a. actual, but band-sprayed 1/3 of row width and therefore equivalent on plants to rate of 60 g.p.a. overall spraying.

** Pretreatment population 0.51 and 2.64 per plant respectively on 24 May.

*** A final count of the number of plants with yellows on 27 September showed an apparent decrease in incidence and has been neglected in the calculation of the infected-plant-week total.

Table 4 Comparison of demeton methyl spray and machine applied phorate granules.

Treatment	% decrease in infected-plant-week totals	Weight of washed beet (tons/acre)	% Sugar	Weight of sugar (cwts/acre)
Control	0	16.0	15.0	48.0
Demeton methyl spray 19 May. (7 oz. a.i. in 70 g.p.a.)	21.8	16.9	15.1	50.8
Demeton methyl spray 15 June (7 oz. a.i. in 25 g.p.a.)	21.2	17.1	14.9	51.2
Two demeton methyl sprays. (as above)	28.7	18.0	15.1	54.4
Phorate granules applied in a 4" band on the foliage 25 May. (22 oz. a.i./acre)	24.3	18.5	15.3	56.6
S.E. per treatment mean.		±0.65	±0.28	±2.30
L.S.D. (P=0.05)		2.00	0.86	7.09

Appendix:

Insecticides used in 1961 field trials and some details of their formulation

Demeton-methyl: 58% W/V miscible liquid.

Dimethoate: 6.9% granules <0.5-4.0 mm. diameter
30% W/V miscible liquid.

Menazon: JF 903 0.5% granules 0.5-1.67 mm. diameter*
JF 938 2.6% " 0.5-1.67 mm. "
JF 703 70% dispersible powder.

Phorate:	10% granules	<0.5-1.50 mm. diameter
	48.2% W/V experimental miscible liquid	
Thiodemeton:	4909 5% granules	0.5-1.5 mm. diameter *
	4909a 5% granules	3-4 mm. diameter
	4909b 2.5% granules	0.5-1.5 mm. diameter
	5127 10% granules	0.5-1.5 mm. diameter
CR5331:	5% granules	0.85-1.4 mm. diameter *

Particle sizes of Granular Insecticides used in the 1961 trials

Material	Percentage by weight of each fraction								
	Less than 0.5 mm.	0.5-1.0 mm.	1.0-1.5 mm.	1.5-2.0 mm.	2.0-3.0 mm.	3.0-4.0 mm.	4.0-5.0 mm.	5.0-6.0 mm.	6.0-8.0 mm.
Dimethoate 6.9%	5.5	11.0	25.5	31.0	22.0	4.0	-	-	-
Menazon 2.6% JF 938**	1.5	9.0	38.0	42.0	10.0	trace	-	-	-
0.5% JF 903	1.0	10.0	45.0	36.5	7.0	trace	-	-	-
Phorate 10% ***	31.0	67.0	1.5	trace	-	-	-	-	-
Thiodemeton 5% 4909	19.5	29.0	43.0	7.5	trace	-	-	-	-
5% 4909a	0.5	1.0	1.5	3.0	6.5	53.0	31.5	2.5	trace
2.5% 4909b	17.0	32.5	32.5	17.5	trace	-	-	-	-
10% 5127	17.5	29.5	34.5	18.5	trace	-	-	-	-
CR5331 5%	1.5	9.0	70.0	19.5	-	-	-	-	-

* manufacturers data.

** JF 938 applied as 5% granules, but subsequent analysis by the manufacturer showed it to contain 2.6% menazon. The amounts of active ingredient applied have been amended throughout the paper.

*** based on one sample only.

THE CONTROL OF SUGAR-BEET VIRUS YELLOWS WITH PHORATE GRANULES

by C. D. Lindley
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Summary

Work is described with phorate, a new organo-phosphorus systemic insecticide, applied as a granular formulation for the control of virus yellows in sugar beet.

It was more effective in controlling aphids when applied topically to sugar beet plants than as a sideband placement. Field experiments carried out over three seasons have shown that a topical application gave excellent and persistent reduction of aphids, reduced the incidence of virus yellows and increased the yield of sugar.

The persistence varied with the rate of application, 1 lb a.i. per acre being effective for approximately 2 weeks, 2 lb for 3 to 4 weeks and 3 lb for 5 weeks.

No detectable residues of phorate (<0.02 p.p.m.) were found in leaves or roots at harvest following the application of 3 lb a.i. per acre.

Introduction

The use of systemic insecticides on sugar beet for the control of aphids and consequent reduction of virus yellows has become standard practice in many areas of England. The British Sugar Corporation have developed a spray warning scheme advising farmers when to spray. In many cases two or even three applications are required to effectively protect the plants during the period of aphid migration and build-up.

The work with topical applications of granulated phorate by Reynolds, Fukuto and Peterson (1960) in California was observed by the author during 1957. They found that phorate persisted in the plants for several weeks and was superior to spray applications of demeton for the control of aphids, leaf-hoppers and mites. There were, however, considerable differences between conditions in California and those normally found in the United Kingdom. In California the plants had dense foliage at the time of application. The aphids were not vectors of a virus disease and irrigation is essential in the cultivation of the crop. Nevertheless, there seemed to be good reason for investigating the topical application of granulated phorate on sugar beet in the United Kingdom and trials began in 1959.

Materials and Methods

An 8% formulation of phorate on attapulgite granules was used in 1959, diluted to 5% with brick dust. In one trial a comparison with 5% phorate on attapulgite granules was made. Subsequent trials were carried out with

the United States commercial 10% phorate on attapulgite granular (24-48 mesh) formulation.

Replicated small plot trials were made in 1959 and 1960, and unreplicated large plot (grower) trials in 1961. Application of granules was made with a Bean seed drill in 1959, and in 1960 with a Gandy granular applicator mounted on a wheelbarrow type frame and propelled by hand. Application on the grower trials in 1961 was made with a Farmery "Micro-Band" granular applicator mounted on a steerage hoe. The plot size was $\frac{1}{2}$ to 1 acre. The spray application of demeton-methyl in the replicated trials were made at 20 gallons per acre.

The design of the small plot trials was a randomized block with four-fold replication, the plot size being 18 to 30 rows wide and 20 yards long. Counts of apterous green aphids were made on between 10 and 20 plants per plot selected at random. Counts of the plants showing symptoms of virus yellows were made on 500 to 1,000 plants per plot. The number of infected-plant-weeks was calculated from the sum of products over successive dates of observation of the number of plants infected and the interval of time between the date of observation and mid-October. The percentage loss of potential yield was calculated on a $4\frac{1}{2}$% loss for each week the plant shows symptoms of virus yellows up to mid-October (Watson, Watson and Hull 1946).

Yields were estimated by lifting nine 30' lengths of rows per plot. Two 28 lb samples of beet were sent to the local British Sugar Corporation factory for estimation of dirt tare and the percentage of sugar.

The residue analyses were carried out using the Laws and Webley method (1961) for determining organo-phosphorus insecticides.

Results

Two trials were laid down in 1959 to compare application of phorate granules in a narrow band on top of the plants (topical) and in a band just below soil level approximately 2 inches to one side of the plants (sideband) with two sprays of demeton-methyl applied 15 days apart. Both trials gave similar results, and the figures for one are given in Table 1.

Table 1 Comparison of Phorate Granules with Demeton-methyl Sprays - 1959

Treatment (a.i./acre)	Date of treatment	Apterous green aphids per 10 plants			% Plants with virus yellows
		26/5	10/6	23/6	30/7
Phorate sideband 1.0 lb	14/5	4.2	17.0	165.0	39.0
Phorate sideband 2.0 lb	14/5	3.7	11.0	87.0	23.8
Phorate topical 1.1 lb	14/5	0.7	2.5	34.7	17.4
Demeton-methyl 7 oz	26/5 & 10/6	-	2.5	4.2	13.2
Control	-	9.7	34.2	1060.5	63.4
Least Significant Difference					
P = 0.05					19.5
P = 0.01					26.9

Sideband application of phorate at 1 or 2 lb did not give as effective a control of aphids as a topical application at 1 lb. The latter treatment gave good initial kill and a count on 10th June showed there were as many aphids 27 days after application as on the demeton-methyl spray 15 days after application. A second spray of demeton-methyl was applied on this date resulting in a lower aphid count on 23rd June than on the phorate plots.

A virus yellows count on 30th July confirmed the superiority of the topical application of phorate to the sideband method. The plots sprayed with demeton-methyl contained less virus infection than the phorate treatments, reflecting the better aphid control in June.

In the second trial the 5% attapulgite formulation was marginally but not significantly inferior to the 8% attapulgite formulation diluted with brick dust, both being used as topical application.

As a result of these experiences, it was decided in 1960 to investigate the effect of different rates and times of application of phorate granules. Three trials were laid down, one near Guildford, one near Mildenhall and one near Ipswich. Results are shown in Tables 2, 3 and 4.

Table 2 Comparison of Topical Application of Phorate Granules with Demeton-methyl Sprays at Guildford Site. 1960.

Treatment (a.i. per acre)	Date of treatment	% Plants infested apterous green aphids				Infected-plant-weeks *	% Decrease inf.-plant-weeks from Control	Yield of sugar (cwt/acre)
		27/5	1/6	24/6	1/7			
Phorate 1.0 lb	27/5	-	0	20	43	857	17.7	59.1
Phorate 2.0 lb	27/5	-	1	23	37	693	33.5	65.0
Phorate 3.2 lb	27/5	-	1	18	13	564	45.9	70.2
Demeton-methyl 7 oz *	27/5 & 13/6	-	1	8	35	640	38.5	62.1
Control	-	60	68	48	73	1041	-	51.6
Least Significant Difference								
P = 0.05						102		6.0
P = 0.01						143		8.3

* Calculated from virus yellows counts 1/7, 3/8 and 5/9.

Table 3 Comparison of Topical Application of Phorate Granules with Demeton-methyl Sprays at Mildenhall Site. 1960.

Treatment (a.i./acre)	Date of treatment	% Plants infested apterous green aphids					Infected-plant-weeks *	% Decrease inf.-plant-weeks from Control
		25/5	31/5	7/6	17/6	7/7		
Phorate 1.2 lb	18/5	0	0	10	16	53	194	35.3
Phorate 2.0 lb	18/5	0	1	8	3	55	175	42.7
Phorate 3.3 lb	18/5	0	1	4	3	32	115	61.7
Phorate 2.2 lb	25/5	-	0	1	4	45	166	44.7
Demeton-methyl 7 oz *	25/5 & 7/6	-	0	4	0	55	147	50.9
Control	-	34	19	18	24	83	300	-
Least Significant Difference								
P = 0.05							90	
P = 0.01							124	

* Calculated from virus yellows counts 27/7 and 6/9.

Table 4 Comparison of Topical Application of Phorate Granules with Demeton-methyl Sprays at Ipswich Site. 1960.

Treatment (a.i./acre)	Date of treatment	% Plants infested apterous green aphids				Infected-plant-weeks *	% Decrease inf.-plant-weeks from Control
		26/5	31/5	14/6	30/6		
Phorate 2.0 lb	11/5	0	3	10	38	144	29.9
Phorate 2.0 lb	19/5	0	8	8	48	159	22.6
Phorate 1.1 lb	26/5	-	0	13	58	125	39.0
Phorate 2.0 lb	26/5	-	0	4	47	107	47.8
Demeton-methyl 7 oz *	26/5 & 14/6	-	0	11	20	121	40.9
Control	-	6	15	21	42	205	-
Least Significant Difference							
P = 0.05						52	
P = 0.01						72	

* Calculated from virus yellows counts 26/7 and 31/8

Phorate granules gave a good initial kill of aphids at all rates at the three sites. The persistence varied with the rate and the time of application, 1 lb being effective for approximately 2 weeks, 2 lb for 3 to 4 weeks and 3 lb for 5 weeks.

At Ipswich, phorate applied on 26th May appeared to persist longer than the same rate applied on the 11th or 19th. This may have been due to the fact that more granules were retained on the foliage of the plants when they were larger. At this site many Coccinellid predators were present. Their distribution was affected by the treatments and they were responsible for some of the anomalous results of the aphid counts. The aphid counts show that each application of demeton-methyl persisted for 10 to 14 days, and that some reinfestation occurred between the two applications.

Rainfall was low following the application of phorate at all sites. At Guildford no rain fell for 11 days after application, followed by one inch in the next week. At Mildenhall there was no rain between 15th May and 5th June, but over one inch fell in the next four days. Conditions at Ipswich were similar except that only about half an inch fell between 6th and 10th June.

All treatments at Guildford gave a significantly higher yield of sugar per acre over the control. The increase with phorate at 1 lb was 7.5 cwt/acre, 2 lb 13.4 cwt/acre, and 3.2 lb 18.6 cwt/acre compared to an increase of 10.5 cwt/acre with demeton-methyl. The yield with phorate

at 3.2 lb was significantly greater than with 1 lb phorate or demeton-methyl.

At Mildenhall there were fewer aphids on two of the phorate treatments on 17th June than on 7th June, although the numbers on the untreated had risen. Perhaps the rain facilitated uptake of phorate by the plants on these treatments three weeks after application.

The reduction in the amount of virus yellows in general reflected the degree of aphid control shown by each treatment, 1 lb of phorate giving a mean reduction of 31%, 2 lb of 42%, and 3 lb of 54%, compared to a reduction of 43% with two sprays of demeton-methyl.

At Ipswich, application on 26th May gave a better control than either on 11th or 19th May, but at Mildenhall there was no difference between application on 18th or 25th May.

In 1961 fifteen unreplicated grower strip trials were carried out to obtain information on the efficiency of different rates of phorate granules applied with a new type of grannular applicator under conditions of grower usage. The remainder of each field was sprayed by the farmer but in seven trials this was carried out several weeks after the spray warning was received. In five trials, two sprays were applied with an interval of approximately 3 weeks.

At eight sites two or more rates of phorate were used, and at four of these, three rates were compared. Results are given in Tables 5 and 6.

Table 5 Comparison of Two Rates of Phorate in Eight Grower Trials. 1961

Treatment	Range of rates (a.i./acre)	Mean rates (a.i./acre)	Mean number infected-plant-weeks*	% Loss of potential yield
Phorate	1.25 - 1.4 lb	1.34 lb	102.3	4.6
Phorate	1.7 - 1.9 lb	1.79 lb	98.4	4.4
Demeton-methyl	7 oz per application ⁺	-	155.3	7.0

⁺ 1 application at 5 sites
2 applications at 3 sites

* Calculated from virus yellows counts in mid-July, mid-August and mid-September.

Table 6 Comparison of Three Rates of Phorate in Four Grower Trials. 1961

Treatment	Range of rates (a.i./acre)	Mean rates (a.i./acre)	Mean number infected-plant-weeks *	% Loss of potential yield
Phorate	1.3 - 1.4 lb	1.35 lb	71.8	3.2
Phorate	1.7 - 1.8 lb	1.75 lb	61.3	2.8
Phorate	1.9 - 2.5 lb	2.1 lb	42.7	1.9
Demeton-methyl	7 oz per * application	-	146.9	6.6

* 1 application at 3 sites
2 applications at 1 site

* Calculated from virus yellows counts in mid-July, mid-August, and mid-September.

Phorate gave effective control of virus yellows in the grower trials and the higher rates of application were slightly more effective than the lower rates. It was more effective than sprays of demeton-methyl but this was largely due to the fact that in certain trials only one application of demeton-methyl was made, this sometimes being badly timed.

The mean number of infected-plant-weeks for all rates of phorate at all sites was 128 compared to a figure of 184 for the spray treatments. The calculated loss of potential yield was 5.8% for phorate and 8.3% for the sprays.

The amount of phorate in the leaves of plants following application at 2 lb per acre was 3.3 p.p.m., after 7 days, 0.5 p.p.m. after 14 days and 0.033 p.p.m. after 28 days in one experiment.

No detectable residues (< 0.02 p.p.m.) were found in leaves seven weeks after treatment with 3 lb per acre and in leaves or roots at harvest.

Discussion

These experiments have shown that a topical application of phorate to sugar beet will give a high initial aphid kill and will persist for several weeks, resulting in a reduced virus yellow incidence. The yield of sugar was measured in only one of these experiments and this confirmed that a reduction of virus incidence was associated with an increased yield.

A comparison of the effect of different rates of phorate shows that there is a greater reduction of yellows at the higher rates, due to their longer persistence. The difference between the reduction obtained at 2 lb per acre and at 3 lb is only worthwhile if a severe aphid attack occurs (e.g. Guildford, Table 4) when the increased yield more than pays for the extra cost of treatment. When there is a less severe infestation (e.g. at other sites, Tables 3, 4, 5 and 6), the extra cost would not be justified.

One application of phorate at 2 lb per acre has generally given as good a control of virus yellows as two sprays of demeton-methyl.

The comparative figures for the control of virus with phorate and demeton-methyl in the grower trials must not be over-estimated for reasons explained previously. These trials are of value in giving additional data on the efficiency of different rates of phorate, and this type of experiment was felt to be a necessary step between replicated small plot experiments with the material and its commercial use by the farmer.

A considerable acreage of sugar beet is annually sprayed twice and the results in certain of the grower trials indicated that at least in 1961 this figure could profitably have been greater. Since it is extremely difficult to forecast the severity of virus yellows at the time of application, it may be advisable to use 1.5 lb to 2 lb of phorate as a routine protectant against a moderate attack.

Experiments carried out on the timing of phorate applications have given some evidence that the persistence is reduced when application is made to small plants (i.e. at 2 to 6 true leaf stage) compared to its use on larger plants. In many of the grower trials in 1961, phorate was applied before the spray warning had been issued, giving a greater reduction of virus than the sprays. Phorate should not therefore be applied to small plants unless aphids are present, but it could usefully be applied once the plants were past the sixth leaf stage if the spray warning had not been received.

It has been shown that granular phorate can be applied commercially to sugar beet by an applicator mounted on a steerage hoe during routine cultivation. There will therefore be little additional application cost to the farmer.

Reynolds et al (1960) suggested that the insecticidal toxicity of phorate applied topically to sugar beet is largely a combination of fumigant and systemic activity. Observations at one site in 1960 showed that the aphids had begun to fall off the leaves onto the ground within 4 hours of applying phorate, and no live aphids were found after 18 hours. This is evidence of fumigant action. The amount of phorate recovered from the leaves shows that uptake can be rapid and that systemic action is likely to contribute to aphid toxicity.

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FIELD TRIALS WITH THIODEMETON FOR THE CONTROL OF APHIDS ATTACKING SUGAR-BEET, POTATOES AND BRASSICAS

by W. Linke, J. D. Forrest and B. G. Hoare
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Following the development of organophosphorus systemic insecticides which are absorbed by leaves and the root system of plants, the possibilities of applying suitable formulations of them to the seed and soil were studied and reported by various workers (Unterstenhöfer 1957a, b; David and Gardiner 1955). Their results have indicated the possibilities of controlling aphids on a number of crops including sugar beet, potatoes and brassicas, using systemic insecticides as seed dressing and granular formulations, the latter being either applied to the soil or as top dressing on to the growing crop.

Our own trials work from 1958 - 1961 was done primarily with thiodemeton (Schrader, 1950), the proposed common name for OO-diethyl-S-2-(ethylthio)ethyl phosphorodithioate. Thiodemeton is a clear oily liquid with a strong odour. The volatility at 20° C. is 2.7 mg/m^3. It is only slightly soluble in water and fairly resistant against hydrolysis up to a pH of 8. The acute oral toxicity on male rats is 12.5 mg/kg, on female rats 2.6 mg/kg and on male guinea pigs 10.8 mg/kg. The dermal LD_{50} of a 50% thiodemeton carbon powder is 70 mg/kg. In our trials work from 1958 - 1961 we were using 2.5%, 5% and 10% granular formulations of thiodemeton, a 5% granular formulation of demeton-S-methyl sylphoxide and a 50% thiodemeton seed dressing. The top and side dressing applications of thiodemeton were in most cases compared with spray treatments using emulsifiable concentrates of demeton methyl, demeton-S-methyl and demeton-S-methyl sulphoxide.

Trials with thiodemeton on sugar beet

Much valuable work on the control of M. persicae and A. fabae, both carriers of Virus Yellows of sugar beet, has been done in the last 10 years in this country (Hull, 1956; 1958; Gates, 1959) using systemic sprays. The prime object of our trials on sugar beet was to compare the effect of various thiodemeton formulations on these two aphid species and the incidence of Virus Yellows in comparison with spray treatments.

In 1958, a 50% thiodemeton seed dressing was included in a replicated trial on sugar beet. Rubbed and graded seed was sown at a rate of 14 lb per acre on the 16th April, dressed with $\frac{1}{2}$-oz, 1 oz and $1\frac{1}{2}$ oz of thiodemeton seed dressing per lb of seed. Demeton-methyl at a rate of 7 oz per acre and demeton-S-methyl at 3.3 oz per acre were sprayed on the 20th May and 18th June. The total numbers of aphids on 20 leaves were recorded on 30th June. On the 9th May, about 8 days after emergence of the untreated plots, the emergence of all plants was scored, no emergence being graded as 0, even emergence as 5. The results are given in Table 1.

Table 1

Treatment	Total No. aphids per 20 plants	Grading of Emergence
Thiodemeton seed dressing		
$1\frac{1}{2}$ oz	48	0.75
1 oz	11	1.50
$\frac{1}{2}$ oz	18	2.50
Demeton-methyl	1	4.5
Demeton-S-methyl	5	4.25
Control	107	4.25
5% L.S.D.	71	1.07

These results, indicating good aphid control but an undesirable degree of phytotoxicity, are in line with those reported by other workers (Dunning, 1960, 1961; Steudel et al., 1959). Consequently work with thiodemeton seed dressing was discontinued and a thiodemeton 5% granular was used in a replicated trial in 1960 at Rowhill Experimental Farm, Kent. It was applied by hand on top of the seed at sowing time (1st April) at a rate of 20 lb per acre, i.e., 1 lb active ingredient per acre. The seed rate was 14 lb per acre and the plots were 1/35 of an acre. Demeton-methyl at 7 oz per acre and demeton-S-methyl sulphoxide at 3.3 oz per acre were sprayed on the 17th June.

The aphid infestation on the 9th July in the various plots given in Table II is expressed as number of green aphids per leaf, whilst for black aphids a scoring system was used grading the degree of infestation from 0 - 4, an index figure being arrived at by multiplying the score value with the number of leaves in each score category. An assessment of Virus Yellows incidence was carried out on the 20th August, 1960 and the weight of topped beet was determined at harvest time.

Table 2

Treatment	Green aphids/ leaves		Black aphids/20 leaves (degree of infestation)	Virus Yellows in %.20.8.60.	Topped beet (Total) lb
	Winged	Apt.			
Thiodemeton 5%	0.4	4.8	11.8	38.5	3804
Demeton-methyl	0.4	5	12	44	5619
Demeton-S-methyl sulphoxide	0.6	5.4	10.6	40	5520
Control	0.2	8.6	43.6	68	5263
	not significant		5% L.S.D.	5% L.S.D.	5% L.S.D.
			11.4	17.6	1113

Despite the fact that the thiodemeton treatments had given good control of Virus Yellows they were lower in yield than the control or the spray treatments and it must be assumed that this reduction was due to phytotoxicity. It was, therefore, decided to discontinue work with this form of application and, in the 1961 trials, to experiment on the application of thiodemeton 5% and 10% granulars as a top dressing, i.e., on to the leaves of sugar beet plants at singling time. Promising results in this country with this type of treatment were first reported by Dunning (1961) who found thiodemeton, applied as top dressing at $1\frac{1}{2}$ lb active ingredient per acre, slightly more efficient in aphid and Virus Yellows control than two demeton-methyl sprays.

It was the aim of our field trials to compare granular formulations of thiodemeton and to a limited extent of demeton-S-methyl sulphoxide under different conditions in Virus Yellows areas. In the larger scale trials we tried to obtain, at the same time, information on the possibilities of applying granular formulations under field conditions with suitable applicators, attached to steerage hoes. By this technique two operations, i.e., insecticide application and hoeing could be combined, a point pertinent to the spring mechanization of the sugar beet crop.

The following account refers only to a cross section of the replicated trials, because space precludes the inclusion of full results of 10 trials in 7 different sugar beet factory areas.

Trial on sugar beet at Rowhill Experimental Farm, Kent

Layout: Randomized block; 1/50 acre plot size. The date of application of thiodemeton was 3rd June and of spray treatments 7th and 22nd June. The rates were thiodemeton 5%: 20, 30 and 40 lb per acre applied as top and side dressing; 5% demeton-S-methyl sulphoxide granular: 20 lb per acre; and demeton-S-methyl sulphoxide: 3.3 oz per acre.

Aphid counts were done on the 6th June and 17th June, whilst the incidence of Virus Yellows was assessed on the 28th July. The results are given in Table 3 where for black aphids the degree of infestation is given using the scoring method described above.

Table 3

Treatment	Aphids per 30 plants				Virus Yellows % 28th July	Root Yield (tons per acre) **	Sugar content in %
	6th June		17th June				
	green	black	green	black			
Thiodemeton 20 lb	1	1	2	9	22	14.1	13.7
5% top 30 lb	1	0	10	9	20	12.2	13.0
dressing 40 lb	6	0	6	0	15.3	13.3	13.3
Thiodemeton 20 lb	33	2	18	27	29.7	13.8	12.7
5% side 30 lb	17	0	23	1	24.7	13.2	13.5
dressing 40 lb	102	0	16	3	25.3	12.5	13.1
5% demeton-S-methyl sulphoxide top dressing	5	9	5	1	29	12.3	13.3
Demeton-S-methyl sulphoxide	not counted		2	1	25.7	12.4	13.6
Control	280	111	148	147	56.3	9.1	13.0

** (estimating 5% dirt tare)

As far as Virus Yellows incidence is concerned the 5% L.S D. between any two means is 15.5 whilst for the root yields the 5% L.S.D. is 2.05 tons.

Ipswich Trial

The layout was 2 x replicated plots 190 yd long and 10 rows wide. The dates of spray treatments were 10th May and 15th June, applied by field sprayer, and that of granular application 10th May, applied by Noble applicator attached to a Ford-Ferguson hoe.

The granular materials were, in this and the following trials, applied as top dressing, i.e., directed to the plants at the 6 leaf stage in a 3" band, a small portion being retained by the plants, the remaining granules falling on to the ground. Results of aphid and virus assessments are given in Table 4.

Table 4

Treatment	pre-appl. green	pre-appl. black	Aphids per 30 plants 31.5 green	31.5 black	21.6 green	21.6 black	Virus Yellows % 18.8.	16.8.
Thiodemeton 5% 20 lb			29	15	33	1045	25.5	33.2
Thiodemeton 5% 30 lb			39	31	18	706	26	38.6
Thiodemeton 10% 15 lb	18	27	15	41	46	1777	17	26
Demeton-methyl twice, 7 oz			7	37	1	70	11	21.8
Control			225	74	472	2328	48	60

Bury St. Edmunds Trial

The layout was 2 x replicated plots 100 yds long and 10 rows wide. The dates of spray treatments were 28th May, 26th June (field sprayer, band sprayed). Granules were applied on 12th May with a Noble applicator attached to Ferguson hoe. Results are given in Table 5.

Table 5

Treatment	Aphids per 30 plants 3.6 green	3.6 black	26.6 green	26.6 black	Virus Yellows % 19.7	15.8	15.9
Thiodemeton 5% 20 lb	4	0	24	1551	4	6.3	20.6
Thiodemeton 5% 30 lb	11	16	19	696	2.7	8.9	23.3
Demeton methyl 3.3 oz/acre	2	1	5*	36	1.8	7	20.6
Demeton-S-methyl sulphoxide $1\frac{1}{2}$ fl. oz/acre	0	10	33**	45	1.6	6.3	17.6
Control	64	14	101	876	11.4	27.25	40.3

* 1 hour after spraying
** Just before second spray

Spalding Trial

The layout was 2 x replicated plots 230 yds long and 10 rows wide. The dates of spray applications were 25th May, 17th June, and of granular application 24th May; with a Noble applicator on Leverton hoe. Results are given in Table 6.

Table 6

Treatment	pre-appl. green	pre-appl. black	Aphids per 30 plants 29th May green	29th May black	15th June green	15th June black	4th July green	4th July black	Virus Yellows % 1 Aug.	Virus Yellows % 24 Aug.
Thiodemeton 5% 20 lb	14	0.6	1	0	36.5		207	121	8.1	20
Thiodemeton 5% 30 lb			0	0	13		126	68.5	3	10
Demeton-methyl 7 oz a.i.			0	0	11		60	17	1.25	8.25
Demeton-S-methyl sulphoxide 3.3 oz a.i.			0	0	23		53	24	1.25	10
Control			14	6	103		469	231	15.5	39

Whilst Tables 4 - 6 refer to aphid and virus control in the Bury St. Edmunds, Ipswich and Spalding trials, we summarize in Table 7 information from the three trials in question, giving average results in terms of percentage decrease of infected plant weeks, sugar content and sugar yield.

Table 7

Treatment	% decrease infected plant weeks	Sugar content %	Sugar yield (cwt/acre)
Thiodemeton 5% 20 lb per acre	43	15.8	68.0
Thiodemeton 5% 30 lb per acre	45.8	15.2	64.8
Demeton-methyl (two applications)	61.9	15.7	73.1
Control		15.3	61.5

Trials with thiodemeton on potatoes

In 1960 a small scale replicated trial was carried out at Rowhill Experimental Farm, primarily to compare the effect of a thiodemeton treat-

ment with four spray applications of demeton-S-methyl sulphoxide on four species of aphids.

The layout was a 4 x 4 Graeco-Latin square. Each plot was approximately 23 x 23 sq.ft., consisting of ten rows each containing 15 plants. Wide strips of unsprayed guard rows separated the plots one from another, and also surrounded the whole experimental area.

The variety was Majestics planted 28th April, 1960 with Best Scotch "SS" grade seed.

The following three treatments were compared: (1) thiodemeton 5% granules at 20 lb per acre, sprinkled on to the potatoes in the furrow at planting time; (2) demeton-methyl 7 oz in 60 gallons per acre; (3) demeton-S-methyl sulphoxide 3.3 oz in 60 gallons per acre.

Thiodemeton 5% was applied once only at planting. The sprays were applied on the 10th June, 1st July, 21st July and 3rd August.

Results

Four aphid species were concerned: Myzus persicae (M.p.), Aphidula nasturtii (A.n.), Aulacorthum solani (A.s.), Macrosiphum solanifolii (M.s.)

Twelve leaves (four top, four middle, four bottom) randomly chosen, were examined on each plot. In addition the crop was examined from time to time between these samplings to see if reinfestation had started.

On 11th June no aphids were found on the leaves from the treated plots but seven apterates of undetermined species were counted on the control sample. In counts on 17th - 20th June again no aphids were seen on the treated samples but a total of 25 apterates were found, as follows: M.p. 5; A.s. 1; A.n. 9; M.s. 10.

On 19th July the only aphids present on the treated leaf samples were two apterates (M.p.) on the demeton-methyl plots; 33 aphids were found on the control leaves, consisting of apterates of M.p. 1; A.s. 1; A.n. 24; Aphis fabae seven of which one was winged.

The assessments of 29th and 30th July are given in Table 8.

Table 8

Assessment of aphids on 29th and 30th July

Aphid Species	Aphids on 48 leaves			
	Thiodemeton	Demeton-methyl	Demeton-S-methyl sulph.	Control
M.p. Apt.	1	0	20	35
Wngd.	2	2	0	3
A.s. Apt.	0	5	1	3
Wngd.	0	0	0	0
A.n. Apt.	0	14	9	45
Wngd.	0	2	1	0
M.s. Apt.	1	14	6	17
Wngd.	0	1	0	4
Total Apt.	2	33	36	100
Wngd.	2	5	1	7

There was a reduction in yield from the thiodemeton plots compared with the other treatments and the control, a reduction involving the average size of the tubers and not their number. The estimated number of tubers in the thiodemeton plots was 1,722, in the demeton-methyl plots 1,694, the mean tuber weight being 0.312 lb and 0.395 lb.

It can be seen that the thiodemeton soil application kept the potatoes virtually free from aphids from the end of April to at least the beginning of August (when the aphids disappeared from the untreated potatoes). This result agrees with the results obtained by Burt and Heathcote (personal communication) who found that in a replicated trial at Efford Horticultural Experimental Station thiodemeton 5% granular applied at planting time on early potatoes kept them virtually free from aphids until harvest time.

Unfortunately it was not possible to arrange for a proper assessment of virus incidence in 1961 at Rowhill Farm. Küthe (1961), however, reports that a treatment at planting time with thiodemeton 5% at a rate of 0.5 and 1 gr. tuber reduced effectively the spread of leafroll virus.

Trials in thiodemeton on brassicas

At Rowhill Farm, demeton methyl, demeton-S-methyl sulphoxide and a 2.5% granular formulation of thiodemeton were applied on spring cabbages on the 17th July, 1961 in order to assess their effect on Brevicoryne brassicae. The liquids were applied by means of an Oxford Precision Sprayer whilst the granules were applied by hand in one case as top dressing and in another as side dressing, i.e., directed on to the soil near the base of the plants. The trial was replicated three times, each plot con-

sisting of 40 plants. At the time of application the plants were heavily infested with Mealy Cabbage aphid. To assess the results 8 plants per plot were inspected on the 2nd August, 1961 and the degree of infestation scored separately on inner and outer leaves. The following scoring was used:

0 = nil aphids
1 = 5 - 15 aphids
2 = 15 - 50 aphids
3 = 50 - 200 aphids
4 = 200 +

To arrive at the degree of infestation the score value was multiplied with the number of plants/leaves in each grade and Table 9 gives the results as mean values per 8 plants.

Table 9

	Degree of aphid infestation after 17 days	
	Inner leaves	Outer leaves
Thiodemeton 2.5% granular top dressing 60 lb/acre	1.4	0.6
Thiodemeton 2.5% granular side dressing 60 lb/acre	6	6.6
Demeton-methyl 9.3 oz/acre	1.4	0
Demeton-S-methyl sulphoxide 4.4 oz/acre	4	0.6
Control	24.6	18.6

In another trial in Suffolk, thiodemeton 5% and a 5% granular formulation of demeton-S-methyl sulphoxide were applied as top dressing by hand on Brussels sprouts on the 30th July, 1961. Demeton methyl and demeton-S-methyl sulphoxide applied as spray served as comparison. There were three replicates, the individual plot size being 1/100 acre.

The effect against Mealy Cabbage aphid was assessed 4 and $6\frac{1}{2}$ weeks after application, grading the infestation in hearts and on the outer leaves separately, thus arriving at an index figure for the degree of aphid infestation as at Rowhill Farm. Ten plants per plot were scored and the results in Table 10 represent the mean of the three replicates.

Table 10

Treatment	Degree of aphid infestation			
	4 weeks after application		$6\frac{1}{2}$ weeks after application	
	hearts	outer leaves	hearts	outer leaves
Demeton-S-methyl sulphoxide granular 5% at 20 lb/acre	4	0	1.3	15.3
Thiodemeton 5% at 20 lb/acre	0	0	0.3	2.3
Demeton-methyl 9.3 oz	5	3	6	20.3
Demeton-methyl 18.6 oz	5.3	4	2.3	21.7
Demeton-S-methyl sulphoxide 4.4 oz	5.6	3.3	6.3	20.7
Control	9	5	5	24

A similar trial was laid down in Bedfordshire on the 17th July, on Brussels sprouts, the plot size being 1/100 acre. The treatments were 3 times replicated. In this trial a higher rate of thiodemeton 5%, namely 40 lb per acre, and a 5% granular formulation of demeton-S-methyl sulphoxide was included. The results were assessed as in the Suffolk and Rowhill trials, 2, 4 and $6\frac{1}{2}$ weeks after treatment and are given in Table 11.

Table 11

Treatment	Degree of aphid infestation					
	after 2 weeks		after 4 weeks		after $6\frac{1}{2}$ weeks	
	hearts	outer leaves	hearts	outer leaves	hearts	outer leaves
Thiodemeton 5% at 20 lb	1.6	0	3.3	0	10	9.6
Thiodemeton 5% at 40 lb	0.6	0	1.6	0	8	7
Demeton-S-methyl sulphoxide gran. 5% 20 lb	5.3	0	5	0	8.3	16.3
Demeton-methyl	0.6	0	5.3	0	12	27
Demeton-methyl	0.3	0	4.6	0	11.6	25
Demeton-S-methyl sulphoxide 4.4 oz	1	0	3.3	0	12	27.3
Control	8.3	0	16.6	0	15	34

Summary and Discussion of Results

(a) Sugar beet

The application of granular formulations of thiodemeton as top dressings to young sugar beet plants in May has, by controlling M. persicae and A. fabae, reduced the incidence and slowed down the spread of Virus Yellows as judged by virus counts taken in July and August from replicated field trials in different areas. Only small differences could be observed between the 20 and 30 lb rate of thiodemeton 5%, and it is doubtful whether they were significant.

In the Rowhill trial a thiodemeton top dressing was slightly better than two demeton-methyl sprays judged by the virus counts at the end of July, whilst at the Ipswich and Spalding trials two spray treatments appeared superior in terms of virus control. In the trial at Bury St. Edmunds the difference between two spray treatments and one thiodemeton top dressing was small and probably not significant.

In those trials where 1 and 2 demeton-methyl spray applications were compared two treatments had given slightly better virus control than one, which is in line with previous findings.

The yield data available so far show that top dressing applications of thiodemeton granules and spray treatments with demeton-methyl and

demeton-S-methyl sulphoxide resulted in considerable increases, both in root weight and sugar content, compared with the untreated controls.

In the Rowhill trial, where the largest yield response was recorded, the 20 lb rate of thiodemeton 5% applied as top dressing gave the highest yield, although it did not differ significantly from the yields obtained with the other granular treatments including side dressing applications of thiodemeton 5% and the yields of the plots sprayed twice with demeton-S-methyl sulphoxide and Bayer 4895 (fenthion).

In the field trials at Bury St. Edmunds, Ipswich and Spalding the 20 lb rate of thiodemeton 5% has increased the sugar yield per acre by 10.5%, whilst two sprays with demeton-methyl resulted in an increase of 18.6%. The recorded increases in sugar content range between 0.2% and 0.8% following thiodemeton treatments, and between 0.2% and 0.6%. In interpreting the results it must be remembered that for thiodemeton the trials conditions were more severe, considering that large scale application of granules with applicators attached to farmers' machinery was done for the first time in 1961. Although valuable experience was gained, the application of the granules was not always as perfect as we would have wished.

In the trial at Rowhill, a side dressing treatment of thiodemeton had a slower effect on the aphids than the top dressing treatment carried out at the same time. This is probably due to the fact that absorption of thiodemeton by the roots was relatively slow, especially under the dry weather conditions prevailing.

The 5% granular formulation of demeton-S-methyl sulphoxide was, at equivalent rates, nearly as effective as thiodemeton 5%, but further trials work is needed to fully evaluate the biological efficiency of this formulation.

Little information is available on the way in which thiodemeton acts on aphids when applied as top dressing. We can only assume that the initial effect on aphids is due to fumigant action following the release of thiodemeton from the granules under the influence of moisture. Penetration into the leaves probably takes place which, assisted by root absorption, produces a systemic effect and is thought to be responsible for the relatively long lasting effect on aphids. After absorption thiodemeton is, within the plant, converted into metabolites by oxidation, firstly of the mercapto sulphur and later of the thiono sulphur (Metcalfe et al., 1957).

The effect of the thiodemeton top dressings on aphids lasted for about 3 - 4 weeks but even 6 weeks after the treatment there was still a notable reduction in aphid numbers compared with the untreated control. In years with very early and prolonged aphid infestation it might be advisable to apply a systemic spray at the time when the effect of the granular applications begins to wear off, particularly if black aphids build up.

Whilst there is a rapid knockdown of aphids following spray treatments with demeton-methyl and demeton-S-methyl sulphoxide it will take somewhat longer under field conditions before top dressing applications with

thiodemeton become fully effective, a fact which should be borne in mind as far as timing of granular applications is concerned. It is felt that the relatively long persistence of thiodemeton would allow an application to be made before aphid infestation starts, thus reducing the early virus infections which are particularly dangerous.

(b) Potatoes

The long lasting effect of thiodemeton on aphids when applied at planting time is encouraging and it is likely that this type of treatment, when combined with roguing, should control the spread of leafroll satisfactorily. This is indicated by Burt, Broadbent and Heathcote (1960) and has been found to be true in the trials carried out by Küthe (1961). Growing on tubers from our 1961 trial at Rowhill and assessing the virus in 1962 should provide own information on this point.

If thiodemeton is to be used for seed production on potatoes the reduction in tuber size observed in the 1960 Rowhill trial might not be a disadvantage. Observations during this season have so far not indicated any adverse effect of thiodemeton on the growth of potatoes. In our trials the thiodemeton was sprinkled by hand along the furrows at planting time and the results suggest that the expanding root system can also absorb the thiodemeton at some distance from the tuber. However, as Burt, Broadbent and Heathcote (1960) point out more basic knowledge about the behaviour of granular systemics in the soil and the effect of soil conditions and plant growth on rate of up-take is required.

(c) Brassicas

In the three trials reported thiodemeton was applied by hand as a top dressing and gave good control of Mealy Cabbage aphids which at the time of application were established in the hearts - a problem which is always difficult to deal with systemic sprays. It is likely that some of the granules of the top dressing are retained in the hearts where they might kill aphids by fumigant action and later by systemic action following leaf absorption. The longer residual effect of the thiodemeton application in comparison to the spray treatment is noteworthy in this connection.

There was no significant difference between the low and the high rate of thiodemeton 5% used in one of the trials and the results obtained in the Rowhill trial showed that good aphid control could also be obtained with an application of a 2.5% granular formulation of thiodemeton.

In the Rowhill trial a top dressing application was more efficient than the side dressing application. A double rate of demeton-methyl improved the control of Mealy Cabbage aphid, but not significantly.

The 5% granular formulation of demeton-S-methyl sulphoxide was less efficient in controlling Mealy Cabbage aphid, which might be due to the lower vapour pressure of this compound.

The results obtained with thiodemeton top dressing in the 1961 small scale trial are encouraging enough to justify larger scale trials next

season when preferably the granules should be applied by suitable machinery.

Acknowledgements

We wish to convey our thanks to the British Sugar Corporation and their field staff who have assisted in finding sites for trials and in assessing the results. Thanks are also due to many farmers who have kindly co-operated in our trials with granular systemic insecticides.

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THE USE OF DIMETHOATE FOR CONTROL OF SUGAR-BEET VIRUS YELLOWS IN GREAT BRITAIN

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Dimethoate (00-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate) was shown, early in its development, to move systemically within plants, and to have a contact LD 50 for Megoura viciae of 5 ppm. The acute oral toxicity to female white rats of very pure dimethoate is 600-700 mg/kg (though laboratory and technical grades are 2-3 times as toxic) (Sanderson and Edson, 1959; Casida and Sanderson, 1961). Dimethoate is therefore a systemic aphicide with a high insecticidal activity, and comparatively low mammalian toxicity. It is, in fact, the first systemic organophosphorus insecticide to be excluded from the list of Scheduled Poisons or Scheduled Substances used in agriculture in England.

The first field trials in Great Britain with dimethoate for control of aphids were conducted in 1957. The work which has been subsequently undertaken in Great Britain for control of Myzus persicae and virus yellows was summarised by Geering and Abel (1961). This report reviews all experimental information available to the present time.

In 1958, trials on sugar beet were designed to assess dimethoate for (i) the control of aphids, i.e. Myzus persicae and Aphis fabae, (ii) its effect on the spread of virus yellows, and (iii) yield effects resulting from control of virus yellows. It is now generally recognised in Great Britain that M. persicae is the more important aphis requiring control, because the greater annual loss of crop results from the spread of virus disease by this species.

At eight sites in East Anglia, latin square trials indicated that the optimum dosage of dimethoate was 4.8 oz/acre. A single spray application in a volume of 40 gal/acre of water was made at each site, the timing being determined by the level of aphid population. The aim was to apply sprays when the spray warning was received from the local sugar beet factory. Unfavourable weather, however, prevented the best timing at all sites.

In the accompanying figure, the result of spraying at the optimum time at Long Melford is illustrated and shows a suppression of the population of M. persicae throughout its period of activity. At some sites the aphis population remained low throughout the season, but where populations were higher, control of M. persicae was demonstrated during a period of 14-20 days following the single spray of dimethoate.

Virus incidence was recorded from mid-July until the end of September. The percentage infection with virus yellows in early September is shown in Table 1. At sites 7 and 8, virus incidence was low, due to very low populations of M. persicae. Sites 5 and 6 showed just over 40% and 30% virus infection on the controls, but these were localities where the spray was applied too late to prevent spread of the virus. Consequently,

analyses showed that significant reduction in virus incidence was only obtained at sites 1-4.

Table 1 Virus Yellows Control : 1958
% Infection on 8th and 9th September

SITE	TREATMENTS	
	Control	Dimethoate 4.8 oz a.i./acre
1. Long Melford	55.2	27.3
2. Shelford	85.3	77.2
3. Kennett	58.6	41.5
4. Gayton	24.9	11.0
5. Booton	41.6	38.2
6. Maldon	33.5	32.1
7. Elsing	13.0	9.6
8. King's Lynn	11.9	7.8
Means	40.5	30.6

L.S.D. for means = 4.99

Yield records were then taken on the four sites where significant reductions in yellows incidence were demonstrated, i.e. Table 1, sites 1-4. These are presented in Table 2, where it will be seen that significant yield increases were obtained at sites 1-3, but not at site 4 (Gayton), where the controls showed the lowest virus infection (24.9%) of the group.

Table 2 Yields in tons per acre : washed roots

SITE	Control	Dimethoate	Recorded increase	L.S.D.
1. Long Melford	15.63	17.59	1.96	± 1.43
2. Shelford	19.24	23.09	3.85	± 2.26
3. Kennett	17.56	19.57	2.01	± 0.99
4. Gayton	26.01	24.44	NIL	N.S.

There were no significant differences in sugar content between treated and untreated crops, at any of the four sites where beet was harvested.

The 1958 results served to show: (a) that a single spray of dimethoate can control virus yellows and increase yield of roots and hence sugar; (b) that correct timing of the spray application is required in order to achieve optimum virus control.

In 1959, when very heavy outbreaks of black aphis, A.fabae, occurred, yield response to spraying with dimethoate and other systemics was attri-

butable to control of both virus yellows and black aphis. Results of trials conducted in 1959 by Dunning (1960) have shown that single sprays of dimethoate increased sugar yield by 59% in one trial, and by 129% in another. Hull (1960a) reporting yield trials from 15 factory areas in 1959, shows that over all sites the average yield increase from a single or double spray of systemic insecticide was 26%. At one site, viz. Ipswich, dimethoate was sprayed (Hull, 1960b). This is in an area where virus incidence is generally severe, and an exceptional response to spraying could be anticipated, if successful, in 1959. At this site a single spray of dimethoate increased sugar yield by 36%.

Recent experimental work has mainly reported comparisons of different aphicides for virus control. During 1959 and 1960, Parry Williams (1961) compared a range of systemic aphicides for control of aphids and virus yellows. In 1960, he showed that dimethoate at 6.4 oz a.i./acre gave satisfactory control of green and black aphids, and significantly reduced the incidence of virus yellows.

Hull (1961) summarised results from 5 trials which tested a single application of various insecticides, including dimethoate, for control of aphids and yellows. At Cambridge, none of the chemicals reduced virus incidence. At Spalding, only slight reductions were recorded, while at Peterborough slight increases in virus incidence resulted from single spray applications. At Dunholme, all treatments except one decreased virus incidence. Near Lincoln, a low level of virus attack was decreased. Within these variable conditions of response, i.e. decrease in virus incidence in 3 out of 5 sites, dimethoate showed an average decrease in yellows incidence of 15%.

Where the aim is to control virus yellows by a single spray application, correct timing in relation to aphis populations is of great importance. This was particularly apparent in 1958, when at Shelford, Booton and Maldon (Table 1), sprays were applied too late for optimum effect. During 1961, Dunning has examined the effects of early mangold fly sprays on subsequent yellows infection. His results (unpublished) justify a closer examination of the effect of an early application of dimethoate at a reduced dosage, e.g. 1.2 oz/acre as recommended for control of Pegomyia betae.

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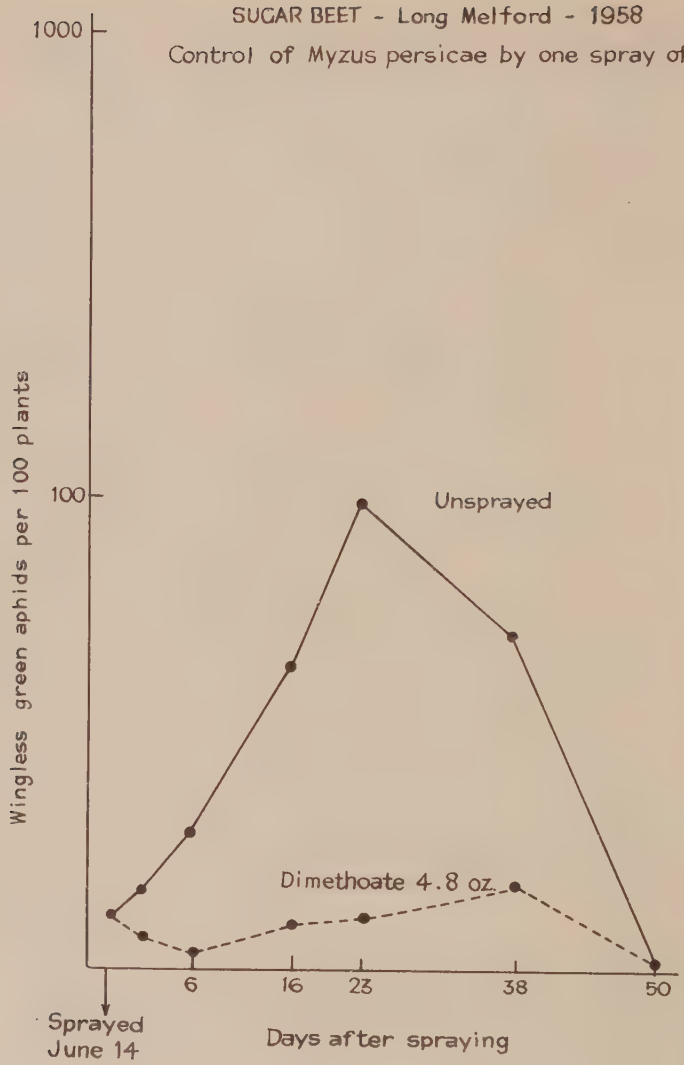
SUGAR BEET - Long Melford - 1958
Control of Myzus persicae by one spray of dimethoate
1000
100
Wingless green aphids per 100 plants
Unsprayed
Dimethoate 4.8 oz.
6
16
23
38
50
Sprayed
June 14
Days after spraying

A PROGRESS REPORT ON THE CONTROL OF APHIDS IN MANGOLD CLAMPS BY METHYL BROMIDE FUMIGATION

by

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In England Broadbent et al.(1949) showed the importance of mangold clamps as sources of viruliferous aphids. In Denmark, Germany, Holland and Belgium also, aphid-infested clamps are considered to be one of the main soucres of yellows virus in the spring. The field staff of the British Sugar Corporation surveyed the incidence of aphids in mangold clamps in beet-growing areas at the beginning of April and of May 1948-57 (Hull, 1955). Over this ten-year period the average number of clamps per square mile ranged from 1 to 2.1 in April, and 0.4 to 0.9 in May, with 5-53% and 11-62% of clamps infested with aphids in the two months respectively. A similar survey over 855 square miles in late April, 1961 covered 2,750 farms; of these 1,482 grew mangolds, red beet or fodder beet, and 962 still had clamps of which 443 were aphid-infested. The aphids on shoot samples from 123 infested clamps were identified in the laboratory; 63% of the samples contained Myzus persicae, 2% M. ascalonicus, 3% Macrosiphum euphorbiae, (M. solanifolii), 9% Aulacorthum solanii, 96% Rhopalosiphoninus staphyleae, and 17% R. latysiphon.

Methods tried so far for dealing with aphid infested clamps in the spring have proved impracticable or have given erratic results. Infestation can be decreased by careful topping in the autumn, but pre-harvest spraying with demeton-methyl proved unreliable (Dunning, 1961b). Neither measure controls Rhopalosiphoninus spp. A direct control of aphids in clamps in the spring is desirable because the whole crop would then not need to be treated, but only clamps found to be infested. Such a method could be recommended as a worth-while investment to individual beet growers, for although the effect of infested clamps can extend widely, they are most obvious and damaging to crops growing near to the clamps.

The susceptibility to methyl bromide of many species of aphids, including those that infest clamped mangolds, has been found to be very high in laboratory tests. Both in the laboratory and in 'microclamps', doses considerably in excess of the LD 99 for aphids caused no damage to several varieties of mangolds except to kill the unwanted sprouts (Dunning, 1961a). Fumigation of infested clamps therefore appeared to be a promising control method and was tested in clamps in Lincolnshire, Cambridgeshire and Suffolk.

Methyl bromide fumigation under sheets is widely used to control insects in many stored products. Workers at Imperial College, in con-

junction with those from the Plant Pathology Laboratory of the Ministry of Agriculture, have adapted this method to disinfest various kinds of plant material, with which uniform distribution of gas is important. The principles so developed have been applied to the fumigation of mangold clamps.

In March-May of 1960 and 1961, 11 clamps were fumigated for periods of 2-17 hours. Clamp volumes ranged from 600 to 8,000 cu.ft., and the coverings were of loose or baled straw, sometimes with soil as well. A 10/1000" unsupported polythene sheet was used for the majority of tests. The efficacy of treatment was assessed by determining the amount of methyl bromide in gas samples taken during fumigation and airing, and by examining mangold sprout samples for live and dead aphids at intervals after the fumigation. All clamps were freed or very nearly freed from live aphids by fumigation. The work is continuing and will be published in full later.

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Discussion

Q. Mr. G. D. Brenner

What type and grade of granules have been used in the field applications?

A. Dr. Dunning

There are two answers I can give. One is to refer you to the table in the paper which includes a lot of information on the size of the granules used. Secondly, we have some samples and I will put these here for everyone to see. So far as the formulation is concerned I will have to refer you to the manufacturers. Is that all right?

Q. Dr. M. A. Phillips

Whilst it is clear that granular insecticides do act, the mode of action needs to be investigated. It is difficult to accept without proof that there can be any fumigant action in the field and systemic action appears to have been demonstrated by residue analysis. What we would like to know is how the material gets into the plant system. Some of these granular materials which we have analysed appear to contain about 5% active material + about 95% Fullers earth or similar substance and no surface active agent or very little.

A. Dr. Dunning

We can say a little about this. Fisons Pest Control very kindly allowed me to refer to some unpublished results of trials. These showed that, in a cage, granules of phorate and thiodemeton have fumigant action. They also showed that a plant will absorb the vapour under these conditions because after the removal of the granules the plants still showed systemic insecticidal activity. They also showed very clearly that if you put these granules in a dish under the plant in the field there is no effect whatsoever. With phorate and thiodemeton granules going on to the plant in the field you will probably get some local fumigant action (this was demonstrated by Lindley in his field trials with phorate) but I do not feel that it is the most important mode of action. This is much more likely to be local absorption through the leaf and petiole - dimethoate granules gave good green aphid and yellows control in Trial III, but this material shows negligible fumigant action in a cage (Fisons Pest Control unpublished results).

Q. Dr. James B. Loughnane

At what stage in the storage period was menazon applied to the potato tubers?

A. Dr. Broadbent

My remarks referred to the soil-applied granular insecticides and not to menazon. This material was sprayed on to the tubers immediately before planting. Granular insecticides are often not fully effective until a few days after the potato plants emerge through the soil. The time presumably depending on root growth and distribution of insecticide in the soil. Mr. Newman has been doing some work with menazon. Perhaps he

can inform us.

Mr. J. F. Newman

In the field, the shoots from menazon treated tubers are toxic to aphids as soon as they emerge from the soil. Tuber treatments are usually applied at, or shortly before planting, but in some cases treatments were made in the chitting house in the proceeding autumn. In all cases, aphid control on the shoots was effective as soon as they emerged from the soil. In the experiments so far made, menazon does not seem to be translocated into the shoots before the tubers are planted.

Summing up - Mr. F. C. Bawden

Given the answers to two questions about the behaviour of an aphid-transmitted virus, it is usually possible to forecast whether spraying with an insecticide is likely to check its spread significantly. The questions are: does it spread mainly from infected to healthy plants within a crop?; can its vectors infect a healthy plant immediately after feeding briefly on an infected one? When the answer to the first is yes and to second no, spraying is likely to be effective, but not when they are the other way round. However, only field experiments can show whether benefits from spraying are economically worth while, establish what to spray with and when to spray. An insecticide may be valuable in one crop but not in another against viruses that have a common vector and behave very similarly. For example, DDT checks the spread of potato leaf roll but not of sugar beet yellows, although both are transmitted by the peach-potato aphid. Systemic insecticides can be expected to be most generally useful, and applying these to the soil at planting time promises to obviate the need to time the first spray as accurately as now must be done to ensure the maximum benefit from spraying. We have had evidence today of notable advances in controlling some virus diseases by attacking the insect vectors, and there is promise that these represent only the beginning of what will become possible.

FORECASTING OF PEST AND DISEASE OUTBREAKS, SPRAY TIMINGS AND ECONOMICS OF CONTROL. POTATO BLIGHT AND ITS CONTROL.

Chairman: W. C. Moore
Ministry of Agriculture, Fisheries and Food

SOME FACTORS INFLUENCING THE CONTROL OF POTATO BLIGHT

by G. H. Brenchley
National Agricultural Advisory Service, Eastern Region

It has been said that potato blight control today is no better than it was thirty years ago. Whether this is true or not, it is certain that the outstanding fact which has emerged from six years N.A.A.S. trials in East Anglis is the failure to achieve any striking and consistent improvement in the control of the disease. In almost every spraying trial, most of the treatments have been significantly better than the unsprayed controls, but very rarely has one treatment been significantly better than the rest. This applies both to trials comparing different fungicides and to those comparing application methods which have ranged from high-volume ground spraying to concentrate spraying from aircraft. These trial results are reinforced by field observations. The average prolongation of growth resulting from three to five sprays seems to be only between a week and a fortnight in a bad blight year, and it is doubtful whether this is appreciably better than the control obtained in the past.

This is not to deny that there have been many advances in the fungicide field, though the advantages of the newer materials often lie in ease of handling, in adaptability to a number of application techniques and, in some cases, in lack of phytotoxicity, rather than in greater fungicidal power. But even among the materials which do possess greater fungicidal activity there is none which has so far shown any marked advantage over Bordeaux mixture in the vital matter of controlling the development of the disease on the haulm.

The most likely reason for this is inadequate fungicidal cover. Leaf prints from crops sprayed with copper fungicides by modern high-volume machines show that even with this technique the cover is far from complete, and unfortunately it is difficult to visualise more than marginal improvements in this respect. Moreover, one cause of incomplete cover, the continuous growth of the plant, is clearly ineradicable. Since the performance of even the best protective fungicide is largely determined by its distribution, and since this appears to be inadequate and likely to remain so, it seems that no striking advance in the efficiency of control can be expected, no matter what further improvements there may be in the materials used. This applies, of course, to protective fungicides of the present type: the advent of a satisfactory systemic fungicide could

alter the whole situation at once.

Control measures which are adequate in a season when the weather does not favour the fungus may fail badly in a year when opportunities for spore-multiplication and dispersal are frequent. When spore numbers are relatively low spraying can at least delay appreciably, even if it cannot prevent, the spread of the disease. Hence the importance of timing the earliest applications so as to ensure that the spraying has the best possible chance: that the fungicide is applied before the spore numbers are already too high.

The best available guide to correct timing is the blight forecasting scheme based on Beaumont's weather criteria. But even when spraying follows the forecast warning as quickly as possible it is still exceptional to get more than a fortnight's delay of the epidemic. This is no doubt partly due to the spraying inadequacies already mentioned, but probably also because what is forecast is not the imminent invasion of the crop by spores from outside but the appearance of the symptoms of the disease. In many fields the actual infection will already have occurred during the Beaumont period on which the forecast was based. Until the conditions necessary for distant epidemic spread can themselves be accurately forecast this weakness will remain, and the first spray, if applied according to the system, will often have to contend with already established infections.

The probability that the key to the failure to achieve complete control lies in the great numbers of spores which have to be repelled, even at what is often regarded as the beginning of the epidemic, directs attention to the conditions in which these spore-numbers are built up. A number of workers - among them Van der Zaag, de Lint and de Bruin in the Netherlands and Hirst and Robertson in England - agree in suggesting that the cryptic or smouldering phase of blight epidemics would repay more investigation.

The earliest phase of all, the development of the primary or "initial" foci, has been studied in this country by Hirst and Robertson. But there is very little information about the next phase - about the way an epidemic builds up in a great potato growing area like the Fens. Practically nothing is known about the number and distribution of initial foci, and how these vary from year to year, nor about the importance or otherwise of the early potato varieties as sources of the blight in the maincrops. It seems that it is in this field that further investigations are most urgently needed.

Recording the early development of a blight epidemic from the ground presents almost insuperable practical difficulties. At Cambridge, therefore, the possibility of using aerial photography for this purpose has been investigated and during the past three years preliminary attempts have been made to survey selected areas in the Fens by this means. The original plan was to photograph an early potato district in the Holland division of Lincolnshire, from which very early records of blight had been regularly received during the previous five years, and a maincrop area near Manea in the Black Fen. The photographing has been done

throughout by Mr. C. V. Dadd, Crop Husbandry Officer, N.A.A.S., Eastern Region.

For recording blight, infra-red materials have proved far superior to panchromatic, giving a much greater contrast between the diseased and healthy areas in a field. Even with this technique, very light infections cannot be recorded, but patches of badly blighted plants only about two yards across can be clearly seen in photographs taken with a $3\frac{1}{4}$" focal length lens from about 3,500 ft., at which height the area covered by one photograph is between three-quarters of a mile and one mile square. Serial photographs, with about 50% overlap, such as are used for stereoscopic examination, are usually taken, though stereoscopy has only proved useful very occasionally, for special purposes. It has been found most convenient to examine the photographs as negatives, still on the original 50-foot roll, using an electrically lighted viewing box. The flight track, potato fields, suspected blight patches and anything else requiring checking by ground examination are then marked on a $2\frac{1}{2}$" map. Positive prints are only made if they are needed for record purposes, for stereoscopy, or for making a mosaic composite photograph of a larger area than is covered by one exposure. There are still many difficulties to contend with in the use of the technique, but they are gradually diminishing with increasing experience and none of them should be insuperable.

Unfortunately from the point of view of this work there has been very little blight in East Anglia in two of the last three years, while in the third (1960) the epidemic started not in Lincolnshire but in West Suffolk. Progress has therefore been slower than had been hoped. But in any case the number of foci and the pattern of epidemic development are likely to vary widely from year to year, so that any survey of this kind must be continued for a number of years before any firm generalisations can be made. In one sense, therefore, it is undoubtedly premature to discuss the subject at this stage, but since the few results already obtained appear to throw light on one aspect of epidemic development it is perhaps worth making a very early progress report.

The first infra-red photograph showing the natural spread of blight was obtained in July, 1960. A focus (probably an initial focus, though this could not be proved) in a small field of Red King potatoes in Sedge Fen, Lakenheath, West Suffolk, was reported on July 4th. At that time it comprised a nucleus, about 2 yards in diameter, of badly blighted plants surrounded by many much less badly infected ones so that the total diameter was roughly 20 yards. No blight was noticed elsewhere in the field or in other fields in the district, though it seems likely that some was overlooked. The field was photographed from the air on July 16th, by which time considerable developments had become apparent. The badly infected nucleus of the original focus was now about 10 yards in diameter and what looked at first sight like another focus of about the same size had appeared a few yards away to the South East. Closer inspection of the photograph showed, however, that this new focus was a composite made up of several smaller patches. At intervals throughout the rest of the field, and still more markedly in another field of Red King

lying to the north of the first field and separated from it only by a narrow strip of wheat, were fifty or more "daughter foci". These varied in size, some consisting of perhaps three or four badly infected plants, others of as many as ten or twelve. Many of these daughter foci, especially the larger ones, somewhat resembled stumpy comets, the badly blighted plants being the 'heads'. From the 'heads', short ill-defined 'tails' of less badly blighted plants stretched for 10-20 yards towards the south-west before becoming indistinguishable from the rest of the crop.

The most distant of these daughter foci was nearly 400 yards from the initial focus, so that this was undoubtedly air-borne spread, such as is normally associated with a Beaumont period. Beaumont periods were recorded at Lakenheath from June 7th - 9th and from June 23rd - 26th. Bearing in mind the size of the daughter foci it seems likely that the larger ones, at least, resulted from spread during the earlier of these periods - June 7th - 9th. This would allow plenty of time for each new infection to develop into a small focus by July 16th when the photograph was taken. This development would be slow at first, in the comparatively dry conditions between the Beaumont periods, but would increase rapidly during the Beaumont period of June 24th - 26th. This late increase might account for the daughter foci not being noticed on July 4th: infections initiated about June 25th might be hardly visible nine days later. The alternative explanation, that the spread from the initial focus did not occur until June 24th - 26th, would imply the descent of spores in "packets" giving simultaneous infection of up to a dozen adjacent plants. It is of course, possible that the ecoclimates in the areas which developed into daughter foci were more favourable than those elsewhere and that this caused a patchy development of blight to result from a heavy but uniform descent of spores during this later period. On the whole the hypothesis of spread during the early June Beaumont period seems the more likely. If this is accepted the formation of the "comet-tails", which appears to involve a type of spread similar to but more rapid than that which normally occurs in an initial focus, may have occurred during the Beaumont period of June 24th - 26th, when very heavy rain was associated with generally light northerly winds.

This somewhat detailed description of one case of spread is given as an example of the kind of evidence that aerial photographs of blight may yield and of the kind of analysis which should be possible. The photographs reveal patterns of blight distribution in a field which could only be perceived from the ground with great difficulty, if at all, still less recorded. Some of these particular interpretations may well be mistaken, but in any case two points of interest emerged from this one photograph alone. The first is that although there was a falling-off in the frequency of daughter foci with increasing distance from the initial this falling-off was by no means steep, and the photograph suggested that had the susceptible crop extended further, the spread might have reached to considerably more than the 400 yards recorded. The second point is that this spread occurred during a Beaumont period (whichever one it was) which would, quite correctly, have been regarded as occurring too early to justify fore-

casting a general outbreak. Even within a mile or two of the fields described, the characteristic sudden appearance of scattered blight in a high proportion of fields only occurred after the next Beaumont period, that of July 9th - 12th.

The warning issued after this period referred to the Sedge Fen focus (then the only case of blight recorded in East Anglia) and prophesied that other outbreaks would occur in the eastern counties before the end of the month. This was entirely correct, but it gave no indication - and could give none on the information then available - of the virulence of the outbreak which was about to occur in this area where W. Suffolk, W. Norfolk and the Isle of Ely join. The rapid development of blight in this district was presumably due, at least in part, to the fact that it was launched not from one initial focus but from some fifty daughter ones as well.

No national forecasting system could possibly cater for the innumerable local variations in climate and in the number of initial foci which must inevitably occur. In this case it is clear that though the national forecast was well timed for East Anglia as a whole it was too late to help the owner of the field in which these daughter foci developed. Further, the very large spore-source which these fields constituted must have diminished the chances of achieving a reasonable check to the epidemic, by spraying, for a considerable distance around.

A similar development of daughter foci at the beginning of the epidemic was seen in one of the very few cases of blight photographed this year. This was again at Sedge Fen, Lakenheath. In a photograph taken on July 25th, two small foci could be seen in a crop of Craig's Royal. They were about the same size and it is uncertain whether they were both initial foci, both daughter (having arisen by spread from some undetected initial) or whether one was an initial which had given rise to the other at an early stage. A smaller patch of blight could also be seen in a narrow strip of King Edwards in the same field, and two, hardly distinguishable, in another King Edward crop in an adjoining field. By August 18th, when the next photograph was taken the Craig's Royal had been lifted, but a number of very clear daughter foci had developed in the second Kind Edward field. This particular case of spread is of interest in that it occurred in weather less humid than a true Beaumont period. No full Beaumont period was recorded at Lakenheath throughout the season.

Only further survey work can determine whether or not this establishment of daughter foci, - occasionally at least well before the general epidemic outbreak - is a common occurrence, though the fact that it has been recorded twice in so short a period and in the very limited areas which have been photographed suggests that it may be one of the normal ways in which epidemics develop. The present evidence shows that it can occur during Beaumont periods in June and sub-Beaumont conditions in July: it is presumably because they are initiated in these border-line conditions for air-borne spread that the daughter foci remain distinct long enough to justify the use of the word "foci".

It remains to consider the bearing of these facts on the control of the disease. The survey has revealed one way in which spore numbers are

built up to a dangerously high level before the general epidemic spread begins and so indicates a possible way of improving the general level of control. If these breeding-grounds of blight - the groups of daughter foci - could be found and eliminated sufficiently early it might well delay the onset of general epidemic spread, or at least reduce the numbers of spores then dispersed to a level with which spraying could deal successfully.

Meanwhile the survey gives some help in answering the perennial question about the value of precautionary spraying before the general outbreak warning. The photographs make it clear that in the fields containing initial foci, or those in which the daughter foci develop, only very early spraying could be of any use. Early spraying should be of value, as an insurance premium, in areas where the risk of being near an initial focus is high - i.e. in intensive potato-growing areas where Kind Edward constitutes a high proportion of the main crop acreage. It is even more justified in such areas if many earlies and second earlies are also grown, for van der Zaag's work in the Netherlands and field experience in this country both suggest that the proportion of initial foci is likely to be higher in earlies than in maincrops. In less intensive areas, and where Majestic is the most common variety, early precautionary spraying is probably too high a premium to pay in view of the comparatively low risk. In districts such as the West Suffolk fenland, where the risk appears to be high, it may also be desirable to supplement the national forecasting system by issuing local warnings after a Beaumont period earlier than that which would be valid for a larger area such as East Anglia as a whole.

Another possible control measure, which would not be popular because it cuts across a convenient practice, would be to isolate the earlies from the maincrop potatoes. Failing this, farmers who grow both side by side should be encouraged to spray them both from a fairly early stage, to inspect the earlies regularly for signs of blight and, if they find it, to destroy the haulm as quickly as possible even at the expense of some loss of crop.

Whether it will ever be practicable to control blight epidemics at or near their source is a question that cannot yet be answered. It will depend largely on how many dangerous sources there are and whether they tend to be sufficiently concentrated in particular areas to make the necessary close search and treatments possible. But if such attempts to reduce the inoculum-potential of blight epidemics are ruled out it seems likely that, so long as we are limited to the use of non-systemic protective fungicides, we must resign ourselves to only marginal improvements in the control of disease.

THE CHEMICAL CONTROL OF POTATO BLIGHT IN THE U. K.

by E. Evans
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The number of compounds currently in use for the control of potato blight in the U. K. is limited and the main objective of this exercise is to present some of the difficulties met in the evaluation of these materials. This is normally done either on a large scale non-replicated basis, or else on a fully replicated statistically designed small plot system. Economic factors do not always permit large scale field trials, but even when this is done, the value of the recorded data must be cautiously assessed. It is traditional to record either yield data or else disease ratings based on some arbitrary key such as that drawn up by the British Mycological Society (1947). Experience with both large and small scale trials in the United Kingdom during the past seven years, has shown that neither method is completely satisfactory, and a compromise system has, therefore, been evolved.

Unless there are application difficulties to be overcome, statistically designed small plot experiments have been found to give the most reliable data. Spray applications are generally started at two weekly intervals well ahead of the blight warnings, and continued regularly until untreated control areas register approximately 5% disease. Regular blight recordings are then made every 3-4 days. Normally the plot size is standardised to 20 square yards and applications are made by means of a hand lance at 50 or 100 g.p.a. Each experiment is always replicated on different sites.

Since the relative amount of disease present in the different treatments varies throughout the epidemic, blight progress curves are drawn for each treatment, using the arithmetic mean of all replicates as points of reference. Two sets of data are then selected for further analysis: (a), an early set of recordings showing maximum difference between the various treatments and the untreated controls; (b), a later set showing maximum differences between treatments, often with certain treatments being not statistically different from the untreated controls. The reason for this procedure is that sometimes the potato crop dies back before treatments reach even the 50% disease level, and therefore further statistical elaboration becomes impossible.

From time to time attempts have been made to take yield data from the small plot trials, but unfortunately this exercise has never proved satisfactory. The data recorded are generally extremely variable even under the apparently uniform soil conditions of the Fenlands, and a statistical analysis of this data rarely shows any significant difference between treatments. The procedure, therefore, has been to estimate yield increases on the basis of the date of 75% defoliation and the published data of Large (1952). It is realised that there are many pitfalls in this procedure, for the published evidence is confined to one variety of potato. However, on the assumption that other varieties yield a similar pattern

of yield increase with time, the relative performance of any two chemicals might be expected to remain fairly constant. Furthermore, this procedure ignores any stimulating or phytotoxic effects that the fungicide may possess.

Table 1 Treatments examined in field trials on potatoes in 1958 & 1960

Active ingredient	Rate of active ingredient per acre	Rate of product per acre
Copper oxychloride	2 or 2.5 lb of combined copper	4 or 5 lb
Zineb	1.3 lb	2 lb
Maneb	1.05 lb	1.5 lb
Copper oxychloride/ zineb	1.125 lb copper + 0.49 lb Zineb	3 lb
Copper oxychloride/ maneb (1958)	1.25 lb copper + 0.525 lb Maneb	3 lb
Copper oxychloride/ maneb (1960)	1.125 lb copper + 0.39 lb Maneb	3 lb

Table 1 lists the treatments examined in 1958 and 1960, and Tables 2 and 3 give the results of four trials carried out in 1958 and four others in 1960. The products used were all orthodox wettable powders, applied according to the recommendations of the manufacturers.

Table 2 Field Trials 1958

Braunton, Devon. Variety- Majestic

Treatments	% disease at point of maximum divergence	Date of 75% defoliation	Estimated % increase in yield over untreated control
	L.S.D. = 16; P = 5%		
Untreated	94%	7th August	0
Copper oxychloride/maneb	38.2	17th "	19.5
Copper oxychloride	50	16th "	19.5
Copper oxychloride/zineb	53	15th "	18.0
Zineb	75	13th "	13.8
Instow, Devon. Variety - Dunbar Standard			
	L.S.D. = 13; P = 5%		
Untreated	95.5	5th August	0
Copper oxychloride/maneb	50	16th "	25.4
Copper oxychloride	67.5	15th "	23.9
Copper oxychloride/zineb	71.5	14th "	21.6
Zineb	90	13th "	19.4
Christow, Devon. Variety - Majestic			
	L.S.D. = 15; P = 5%		
Untreated	93.5	17th August	0
Copper oxychloride/maneb	28.8	26th "	11.8
Copper oxychloride/zineb	34.5	26th "	11.8
Copper oxychloride	37.5	25th "	10.7
Zineb	53.0	25th "	10.7
Ashburton, Devon. Variety - Majestic			
	L.S.D. = 13; P = 5%		
Untreated	90	6th August	0
Copper oxychloride/maneb	23.3	18th "	24.4
Copper oxyc oxychloride/zineb	41.0	17th "	24.4
Copper oxychloride	50	16th "	22.5
Zineb	53.0	16th "	22.5

Table 3 Field Trials 1960

Ashburton, Devon. Variety - Ulster Dale

Treatments	% disease at point of maximum divergence	Date of 75% defoliation	Estimated % increase in yield over untreated control
	L.S.D. = 18; P = 5%		
Untreated	96	31st July	0
Copper oxychloride/maneb	12.5	10th August	30.8
Maneb	26.5	9th "	28.0
Copper oxychloride/zineb	42	8th "	25.2
Zineb	50	7th "	22.0
Meeth, Devon. Variety - Dunbar Standard			
	L.S.D. =16.6; P=5%		
Untreated	80	8th August	0
Maneb	28.5	13th "	13.6
Copper oxychloride/maneb	32.5	12th "	8.7
Zineb	53.5	11th "	6.5
Copper oxychloride/zineb	68.5	10th "	4.5
Chesterford Park. Variety - Majestic			
	L.S.D. =10.2; P=5%		
Untreated	85	30th August	0
Copper oxychloride/maneb	15	11th "	9.2
Copper oxychloride/zineb	28.7	10th "	8.5
Maneb	40.6	10th "	8.5
Zineb	50	8th Sept.	6.9
Chatteris. Variety - Ulster Supreme			
	L.S.D. =17.5; P=5%		
Untreated	92.9	25th August	0
Maneb	15	1st Sept.	7.4
Copper oxychloride/maneb	19.2	1st "	7.4
Zineb	34.2	1st "	7.4
Copper oxychloride/zineb	50	31st August	6.6

The data given in Tables 2 and 3 show quite clearly that the relative performance of the different products varies from trial to trial; any true evaluation of these products must therefore include a consistency factor as a further criterion on which to make a final assessment. From this point of view the performance of mixtures of copper and dithiocarbamates appear to have some advantage over the use of either constituent alone.

In discussing the significance of synergism as a possible tool in the conservation of fungicides, Dimond & Horsfall suggested, as early as 1944, the possibility of synergism between certain copper and zinc compounds. It appears, however, that the first field experiments with mixtures of copper and dithiocarbamates were not reported until 1953 when Lafon & Couillaud in Europe, and Strong in the U.S., published their results on Downy Mildew of vines, Plasmopara viticola, and various diseases of tomatoes respectively. At that time they suggested that the enhancement of activity of the mixture of copper and zineb was possibly related to the solubility of the copper ingredient. Lafon & Couillaud claimed that the mixture of copper oxychloride and zineb showed synergistic activity, but Strong made no such claims. Since 1953 synergistic effects of copper/zineb mixtures have been reported by Payen et al. (1954), Agulhon & Amphoux (1955), Bisson & Larrieu (1958) and Cole (1957). In these studies on mixtures of various copper preparations with zineb, stress was given to the fact that the greatest improvement in activity was obtained with a mixture containing a high proportion of copper and that mixtures of low copper content were not as effective (Agulhon & Amphoux, 1954; Bisson & Larrieu, 1958 and Boubals et al., 1956).

The use of mixtures naturally suggests the possibility of chemical interactions between the ingredients. Strong (1955) thought that the copper salt of the dithiocarbamate might be formed when these mixtures were prepared, and proceeded to demonstrate that the copper salt of nabam gave results equal to that of maneb against Septoria leaf spot of tomatoes. In 1957 this work was repeated with Early Blight and Late Blight of tomatoes and again the possibility of a copper salt being formed was mentioned. Since that time mixtures of copper and zineb have successfully been employed for the control of Leaf Spot Disease of bananas (Cercospora musae), Guyot 1954, and Late Blight of potatoes (Phytophthora infestans), Calbeck 1960.

At the dosage rates used in these experiments it is perhaps prudent to note that maneb gave consistently better control than zineb and similarly copper oxychloride/maneb mixtures gave better control than copper oxychloride/zineb mixtures. However, despite the claims of previous workers that certain mixtures show synergistic activity there is no evidence presented here that this is so. There is, however, a suggestion that the performance of a copper product is favoured by a certain kind of epidemic and that the dithiocarbamates perform better under another set of unknown conditions. Although not presented in this document, the pattern of the blight progress curves for each of these trials suggests that the dithiocarbamates are favoured by the more rapidly advancing epidemics, whereas the more prolonged epidemics favour the performance of copper products.

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TRIALS OF COPPER FUNGICIDES
ADAPTATION OF BORDEAUX AND BURGUNDY MIXTURES FOR LOW VOLUME SPRAYING

by
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Experiments made to adapt Bordeaux and Burgundy Mixtures to low volume spraying have shown that Bordeaux Mixture can be sprayed through nozzle booms at 1 lb copper in 10 gallons, by rotary atomisers at 1 lb in 4 gallons. These rotary atomisers will spray Burgundy Mixture at 1 lb copper in 4 gallons or the new Potash Burgundy at 1 lb in 2 gallons.

Costs of these mixtures are found to be from half to three quarters of those of wettable powders for same copper content.

Mixing procedures are described and suggestions made for minimising difficulties.

The original Bordeaux Mixture announced by Millardet in France in 1885 contained about 6 lb copper sulphate 11 lb quick lime and 10 gallons water which it was advocated should be applied with a brush made of twigs. A few years later with the appearance of the first knapsack spraying machines the mixture underwent modifications to make it sprayable through these machines and a 10:10:100 (10 lb copper sulphate, 10 lb quicklime, 100 gallons water) quickly emerged as a more or less standard mixture.

About 1927 in this country hydrated lime was suggested in place of quick lime and the present Ministry of Agriculture recommendation for a good Bordeaux Mixture for potatoes, for example, is one containing 10 lb granulated copper sulphate and $12\frac{1}{2}$ lb of best hydrated lime in 100 gallons of water, ($10:12\frac{1}{2}:100$). If allowance is made for the smaller calcium oxide content of the hydrated lime it will be seen that the ratio of copper sulphate to calcium oxide has not materially changed over the passage of the past 70 years or so.

Burgundy Mixture was introduced only a year or two later than Bordeaux Mixture. It is made by mixing solutions of copper sulphate and sodium carbonate (soda ash or washing soda) and may therefore be described as a Bordeaux Mixture made with soda instead of lime.

In spite of their antiquity it seems to be generally agreed that freshly prepared Bordeaux and Burgundy Mixtures are the most effective of the copper fungicides. (Beaumont, Bant & Storey, 1953; Moore, 1955; Narayanan, 1955; Grainger, 1957; Saltzman, 1957. There is no doubt this is mainly due to their adhesiveness and consequent resistance to wind and rain.

The reduction in the volume of spray normally used from the original 100 or more gallons per acre to 50, 20 or less together with the higher

cost of farm labour and perhaps its lack of skill has produced a marked but unfortunate tendency to use less effective but more easily applicable copper fungicides in spite of their higher cost. It seemed desirable therefore to try to find ways of overcoming difficulties in the use of these more effective mixtures.

If the same quantity of copper is to be applied per acre in a much reduced quantity of water the thickness of the mixture will obviously be correspondingly increased. This sets a limit to the reduction of volume that can be used and we have investigated what this limit might be in practice.

As a first step in keeping the more concentrated mixtures of a consistency fluid enough to spray the quantity of lime was considered. The conventional use of a large excess of lime was probably dictated by uncertainty of its quality although there have been suggestions that it had some effect in reducing phytotoxicity. Actually 100 lb of copper sulphate ($CuSO_4$, $5H_2O$) requires only $22\frac{1}{2}$ lb of chemically pure hydrated lime $Ca(OH)_2$ to precipitate all copper. Good proprietary brands of hydrated lime are now freely available but as even these deteriorate on storage it was thought safer to adopt a ratio of copper sulphate to hydrated lime of 2:1 and this was found to thin the mixture materially. Burchfield et al. (1956a, b) have shown that such a reduction has beneficial effects on the adhesiveness and persistence of Bordeaux Mixture. We applied such mixtures to potatoes at 9 difference sites in the seasons 1958/61 inclusive without any copper damage being detected by ourselves or the N.A.A.S. in co-operation with whom most of the trials were carried out.

The use of a small quantity of wetting agent was found to increase the free flow of the mixture and was used in some cases at 4 oz per 100 gallons of Bordeaux. That used was of the polyethylene oxide type and was chosen as it had been found to be one which did not materially reduce the deposit (Somers, 1957) and which was very similar to, or identical with, the one adopted for use in Bordeaux Mixture applied to bananas.

Bordeaux Mixtures of formula 8:4:x were sprayed by machines of the following types: (1), Spray boom, pump operated, generally applying 20 to 60 gallons/acre; (2), Tractor drawn, fitted rotary atomisers, applying under 8 gallons/acre; (3), Aeroplane, fitted with rotary atomisers; (4), Motorised, shoulder mounted machines of about 2 gallons capacity in which the spray mixture is fed into a rapid fan-produced jet of air, and (5), Aeroplane, fitted with spray boom, used for Potash Burgundy only.

The practical limits of sprayability of Bordeaux Mixture were considered to be, after several trials:- (1), 8: 4: 20 (= 1% w/v Cu); (2) & (3), 8: 4: 8 (= 2.5% w/v Cu) and (4), (: 4: 4 (= 5% w/v Cu).

With a wetting agent Bordeaux Mixture 8: 4: 4 was used successfully also in type 2 but stoppages at this concentration cannot be ruled out and it is not recommended.

The preparation of Bordeaux Mixture in the field conjured up a vision of a number of men blue from head to foot laboriously poling barrels of

thick liquids. This view however is quite out of date. Some quick and simple procedures are detailed in the appendix but these are obviously capable of many modifications to suit the facilities available. Copper sulphate is now normally supplied in granulated form and this dissolves very much more quickly than the large crystals once standard. For spraying at 20 or more gallons per acre sufficient water is available to dissolve the necessary quantity of granulated copper sulphate in 2 or 3 minutes. For spraying at under 10 gallons per acre time is saved by preparing the copper sulphate before hand, conveniently the night before. Where much spraying is to be done the provision of some storage vessels raised sufficiently to deliver into the sprayer is a matter of comparatively little difficulty and the time required then to make the mixture is no greater than that required to mix a wettable powder. Another way which may appeal to the smaller user is to buy copper sulphate in solution, now available in plastic containers from suppliers of agricultural chemicals.

The sprayability of Burgundy Mixture in concentrated form is considerably greater than that of Bordeaux Mixture. We made it to a formula of 8: 5: x where the second figure refers to soda ash (anhydrous sodium carbonate). The solubilities of the two ingredients (copper sulphate and soda) in cold water limit the concentration in practice to 8: 5: 8 (theoretically about 8: 5: $5\frac{1}{2}$). This mixture sprayed easily through machines fitted with rotary atomisers and more easily than the Bordeaux Mixture of same copper content. No higher concentration than 8: 5: 20 was tried in boom sprayers as this is equivalent to 2 lb of copper in 20 gallons below which volume per acre they are not normally operated with fungicides. If washing soda is used instead of soda ash 12 lb will be required instead of 5 lb of soda ash, and the formula becomes 8: 12: 8.

The practical limits of concentration found for the two previous mixtures (8: x: 8) would in most cases be too weak for economical use by aeroplane. To apply 2 lb of copper per acre would necessitate the application of 8 gallons of mixture and this would limit the acreage per flight to 5 for the machines commonly in use here.

As already pointed out the solubility of the ingredients is the limiting factor in the case of the Burgundy and, of the two ingredients, the soda is the less soluble. Potassium carbonate is very much more soluble than sodium carbonate and the substitution of this enabled a mixture to be made of formula 8: 5: 4 where the second figure refers to potassium carbonate 96/98%. This was found to have good suspension properties and much less tendency to build up on filters than Bordeaux Mixture or even than Burgundy Mixture.

This Potash Burgundy was applied without any trouble by rotary atomisers at 8: 5: 4 and by aeroplane fitted with a spray boom at 8: 5: 5. It was also sprayed from the ground by boom at 8: 5: 16. No higher concentration being tried with the two latter.

Effectiveness of the Mixtures.

During four seasons the above concentrated mixtures were sprayed on potato crops, using the machines metnioned, as part of the N.A.A.S. trials and alongside trials of other products and other concentrations specified by N.A.A.S. whose pathologists evaluated results. Owing to very bad weather in some seasons and absence of blight in others evaluation had to be based mainly on the distribution and persistence of copper on the leaves. The method used was to press the leaves on absorbent paper previously wetted with acetic acid (to dissolve the deposit) and a sensitive reagent for copper (bis cyclohexanone oxalyl dihydrazone). On exposing the paper to ammonia gas any part of the leaf which has a copper deposit leaves a blue mark and after a satisfactory spraying the outlines and ribs of the leaves are clearly printed together with blue speckles on their surfaces wherever copper had been present. This was systematically done by the N.A.A.S. and ourselves both just after spraying and again a week or two later (generally just before the next spraying). Comparisons of the two sets of prints enabled the persistence of the deposit to be judged. This method showed the distribution and persistence of these concentrated sprays to be equal to, and often better than, those of other copper fungicides or of those sprayed at higher volumes.

Costs

The following figures are approximate only as costs vary with market prices, quantities involved, delivery site and other factors. They are based in each case on an application of 2 lb of copper (8 lb copper sulphate) per acre, and prices, per lb, of copper sulphate, 9d; lime, 1d; soda ash, 2d and potassium carbonate (96/98%), 8d.

Bordeaux mixture		6: 4d per acre
Burgundy mixture		7: 0d per acre
Potash Burgundy		10: 0d per acre
Copper Oxychloride	4 lb at 2/9d	11: 0d per acre
Cuprous Oxide	4 lb at 3/2d	12: 8d per acre
Proprietary Powders	Up to	30: 0d per acre

The Potash Burgundy is more expensive than the soda Burgundy but the potash it contains has fertiliser value which though small, may be of significance applied to the foliage when the crop is bulking.

APPENDIX

Mixing Procedures

Bordeaux Mixture

(A) 1. Place the hydrated lime on the strainer and wash in with the bulk of the water.

2. With the agitator working pour in the pre-dissolved copper sulphate solution taking care to avoid any of it coming into direct contact with the steel sides of the spray tank.

(B) 2. Place the finely granulated 'instant' copper sulphate on the strainer and wash in with about half to two-thirds of the water with the agitator working so that any small particles which may fall to the bottom of the tank are dissolved.

3. Place the hydrated lime on the strainer and wash in with the remaining water still with the agitator working.

Method (A) will of course have to be employed where the spray tank is made of steel.

Burgundy Mixture

Dissolve separately 8 lb of copper sulphate in half the water or just a little less and soda ash $4\frac{3}{4}$ lb (or 12 lb washing soda) in the remainder of the water. Stir the copper solution and slowly add the soda solution allowing time for froth to subside.

Potash Burgundy Mixture

(A) For solutions up to 5% of copper sulphate
Place the potassium carbonate on the strainer of the spray tank and wash in with half to two-thirds of the water. If the sprayer tank is efficiently agitated the potassium carbonate may be put straight into it. Dissolve the copper sulphate in the remainder of the water and add it to the spray tank while stirring.

(B) For solutions stronger than 5% (up to 20%) copper sulphate
Dissolve the potassium carbonate in water using about 1 pint per lb. Separately dissolve the copper sulphate in the remainder of the water. Add the potassium solution to the copper sulphate solution slowly with stirring allowing time for frothing to subside.

The vessel used for mixing B should have about twice the capacity of the final volume to avoid loss.

For the preparation of copper sulphate solution use always granulated copper sulphate ('instant'). Iron or galvanised vessels must not be used. Wooden barrels are suitable. Plastic vessels now freely available are light and very convenient. To make strong solutions hang a jute sack of copper sulphate so that the bottom of it dips a few inches only into the water. The copper sulphate will dissolve overnight and it will be necessary only to stir the solution once or twice next morning to mix top with bottom. Copper sulphate will dissolve in water to the extent of about 3 lb

per gallon. If more than this is put into the sack described above then overnight (or later) a nearly saturated solution will be obtained and it may be used without serious error on the basis that it contains 3 lb of copper sulphate per gallon. This is a convenient method.

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Details of Discussion

Q. Mr. H. C. Mellor

Could Mr. Brenchley give any blight figures on the resultant tubers from the crops featured in the aerial survey photographs? Also what differences were observed between the ground estimates of blight incidence and the aerial photograph technique?

A. Mr. G. H. Brenchley

We have concentrated so much on the early stages of blight that we have not followed through with the later stages. As regards the difference between this kind of recording and field recording by observers, I can only say that when we have sent people out to survey a field from the ground they come back with something that is recognisable but often wrong in proportion and with a great deal of detail missing.

Q. Mr. O. H. P. Wood

Mr. Brenchley stated that the newer types of organic fungicide introduced for potato blight control over the last few years showed little advance on traditional spraying of copper based sprays. Mr. Brenchley mentioned phytotoxicity of copper, but only briefly, inferring that this was of little importance. Recently introduced maneb formulations have been shown to be equivalent to copper in fungicidal activity without phytotoxic effects on the crop - would Mr. Brenchley please comment on this?

A. Mr. G. H. Brenchley

I would agree entirely. What I said, or what I meant to say, was that there was no appreciable improvement in the control of the disease on the haulm. In fact, we have found that when the control of the blight on the haulm is the same, zineb and maneb may give a slightly higher yield than copper. To sum up, if persistence is important, copper may stand you in good stead, but otherwise the choice will be with the dithiocarbamates on the score of their lack of phytotoxicity.

Dr. E. Evans added to this:

The Fenland soils are as standard as you get in this country and yet we get variations there. We grew potato plants in standard compost in drums out in the open, artificially watered through all the hot weather we had earlier in the season, using an early variety of potatoes. We sprayed every 10 days through the whole period - we made 8 applications in all. We harvested and hoped to find differences in the yield, but we did not find them. This is indeed a problem!

Q. Dr. James B. Loughnane

Could the inconsistent results in your experiments be explained on the basis of the particular race of Phytophthora infestans involved or on varying conditions such as temperature or relative humidity at the time the sprays were applied?

A. Dr. E. Evans

We have not found anything startling with any of these factors ourselves, but possibly what accounts for much of this variation may be the different yields from any one potato plant. We standardised the number of eyes on a potato tuber when it was planted, but we found that the number of stems produced from one tuber varied from 6 - 16 and the yield from potatoes in one treatment varied immensely. Whether we can pick potatoes that will yield more uniformly I do not know, but I think this should be possible.

PEA MOTH ON DRY HARVESTING PEAS

Investigations into the Timing of Sprays, the Economics of Control Measures and Forecasting the Levels of Attack

by
H. J. Gould and T. J. Legowski
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One of the main changes in the pattern of entomological advisory work in recent years has been the increased emphasis given to the assessment of pest damage and to the economics of control measures. This usually calls for accurate information about the loss caused by a pest and the benefit obtained from the use of pesticides. More attention has also been given to means of forecasting the severity of attacks to enable the grower to take the necessary precautions and to prevent unnecessary spraying.

The pea moth investigations described below were done with these considerations in mind. This paper presents an outline of the whole programme and some of the more important results obtained covering its three main aspects: (1) assessment of the economic importance of the pest; (2) timing and the efficiency of sprays and the economics of control measures; and (3) spray warnings and forecasting the severity of attacks.

The Economic Importance of Pea Moth

Surveys of pea pests in 1957-1959 indicated that in the Eastern Region pea moth was the most important pest on dry harvesting peas (Gould, Legowski and Mason, in press). The surveys were made in three of the main pea growing counties of the Region: Essex, Isle of Ely and Lincs. (Holland) growing about 40 per cent of the total dry pea acreage in England and Wales. A summary of the results is given in Table 1.

Table 1 Summary of the Survey Results, 1957-1959

Year	No. of fields visited*	No. of fields sprayed	Estimated % loss of peas due to pea moth	
			Sprayed fields	Unsprayed fields
1957	53	12	6.5	6.5
1958	29	6	6.0	9.5
1959	111	47	5.8**	11.3

* Fields visited within about 14 days of harvest
** Significantly lower than unsprayed fields at $p = 0.05$

The data obtained during the surveys included the percentage of pods infested, the number of larvae per pod, the number of peas damaged by one larva and the number of peas per pod. Using this information and knowing the prices paid to the grower, which depended on the cleanness

of the sample, it was possible to estimate the losses due to pea moth in terms of money and in equivalent acres. The estimate was (Legowski and Gould, 1960) that on the annual average during 1957-1959, the growers in the three counties lost about £100,000 or approximately 10 per cent of the value of the crop, representing between 6 per cent and 9 per cent of the dry pea acreage. This loss was sustained in spite of the control measures taken which were estimated in 1959 to have cost some £30,000.

Timing and the efficiency of sprays and the economics of control measures

Table 1 indicated that the control obtained by spraying was unsatisfactory, which was also the opinion of many growers. (The majority of growers who sprayed used one application of DDT although in 1959, about 20 per cent of the growers visited used other materials, mainly parathion).

Field and observations and trials in 1958 (Gould and Legowski, 1959) and in 1959-60, suggested that incorrect timing of sprays was one of the main reasons for the poor control. Growers sprayed at or soon after flowering which is correct for peas sown in April and May (Wright and Geering, 1948). In East Anglia, however, the normal sowing time for dry harvesting peas is in February or early March and they usually flower before moths are about and well before eggs are laid. Correct timing is particularly important where only one instead of two sprays is being used and even with two sprays, better results could be expected if the first spray was timed by the presence of moth or eggs in the crop (Table 2).

Table 2 Timing and efficiency of DDT sprays on dry harvesting peas

	% reduction in pod infestation with high volume DDT sprays				
	1958		1959		1960
Timing of first spray	Flowering	First moths	First moths	First eggs	First eggs
Two sprays	42*	71*	62*	62*	70*
One spray	-	40*	-	50*	-
% infested pods on controls	21.0		23.75		18.3

* Significantly different from controls at p = 0.05

The importance of correct timing of pea moth sprays indicated an immediate need for information on the date of moth emergence and egg laying so that growers could be advised of the best time to spray.

The results of our insecticide field trials in 1958, '59 and '60 (Table 2) showed, however, that even with good timing the control obtained with the available insecticides was far from perfect. At the most, a 70 per cent reduction in the percentage of pods infested was obtained with two sprays and 50 per cent with a well-timed single spray. Surveys indicated that about 50 per cent control was also obtained by the growers, mostly with a single spray of DDT, in 1959 and probably an even poorer control in 1957 and 1958.

To assess the economics of spraying, it was necessary to consider the efficiency of the treatments, cost of different methods of application, including the damage to the crop, the actual loss of peas at different levels of pod attack, the price structure for peas according to the level of pea moth "wastage" * and the final yields. Taking these factors into account, it was possible to assess the approximate levels of pod attack at which spraying could be expected to pay for itself (Legowski and Gould, 1960). Table 3 shows this figure for fields with an expected yield of 23 cwt per acre.

Table 3 Minimum pod attack necessary to recover the cost of spraying at an average yield of 23 cwt per acre

	One spray (50% control)			Two sprays (70% control)		
	Grower	Contractor		Grower	Contractor	
		Air	Ground		Air	Ground
Average cost of spraying per acre (including wheeling damage)	70s.	70s.	95s.	110s.	140s.	150s.
Minimum % pod attack needed to recover costs	18	18	23	21	28	

Improvement in the control obtained would obviously affect the economics of spraying. Thus, with a 90 per cent control, the minimum levels of pod attack at which two sprays should pay for themselves would be reduced to about 16 per cent if done by the grower and 23 per cent if done by the contractor.

The data in Table 3 would not be greatly affected by a change in the price for peas if the scale of price reductions for wastage remained the same.

* "Wastage" is the factory term for loss of peas due to staining, splitting or pea moth damage.

It appears that with existing materials and prices, the economics of control measures are not very favourable to the grower, especially in areas or years of average or low yields. Pod infestations of at least 21-28 per cent are necessary to justify two sprays and such levels of attack are not very common. It was estimated that in 1959, a year of heavy attack, on about half of the sprayed fields the cost of spraying probably out-weighed the likely gain (Legowski and Gould, 1960).

In these calculations no allowance has been made for the possible effects of pea moth sprays on other pests of peas, e.g. thrips, midges or aphids. During the three years' surveys, none of these pests appeared to be widespread and economically important on dry harvesting peas, although occasionally thrips and aphids may play a part. It is difficult to evaluate the long-term effect of existing control measures on residual populations of pea moth in any area. However, with the poor control obtained it is unlikely that spraying would be an important factor.

Spray warnings and forecasting the severity of attacks

Spray Warnings

In view of the importance of correct timing of sprays and the economic implications, a warning service to advise the grower when to apply the first spray was introduced in 1959 and continued in 1960-61. The warnings were based on the early presence of eggs on peas and were issued each year through the county N.A.A.S. advisers, through the press and lately through Anglia Television. This information has also been passed to the Pea Growers Research Organisation and to some of the canning firms and spraying contractors.

Since spray warnings should preferably be based on field rather than on artificial cage conditions, our observations on moth emergence and egg laying have been made in the field. The early moth emergence was determined by sweeping and searching for moth on suitable days, twice weekly from late May, on several fields previously under dry harvesting peas and in the adjoining hedgerows (emergence sites). After the first moth was found, similar observations were made on fields of early drilled peas which had reached or passed the flowering stage. At the same time, samples of 10 plants were taken from the headlands of each field for examination for eggs in the laboratory. When eggs were found, note was also made of their stage of development (Hanson and Webster, 1936).

Spray warnings were issued when the first eggs had been found on the majority of sites under observation. The actual dates for 1959-61 are shown in Table 4.

Table 4 Observations on pea moth emergence and egg laying

Year	First moths in cages	Emergence sites		Pea fields			Approximate time of 'peak' egg laying	Date of warning
		Number visited	First moth	Number visited	First moth	First egg		
1959	26.v	12	2.vi	12	5.vi	5.vi	Last week of June	15.vi
1960	23.v	13	30.v	18	7.vi	7.vi	Last week of June	18.vi
1962	19.v	13	23.v	20	5.vi	9.vi	First week of July	14.vi

The spray warnings were issued on the understanding that they did not necessarily imply a need to spray and were only intended to help those growers who wished to spray. It was also made clear that they applied only to crops which had reached or had past flowering.

Sampling for eggs was continued throughout the summer to establish the approximate period of 'peak' egg laying (Table 4). Eggs have been found on peas through to late July when the crop is usually beginning to dry off. The work has also shown that results based on sweeping or searching for moths in peas can be unreliable as on some field eggs have been found before moths were detected.

Forecasting of Attacks

The economic aspects of control measures also led us to explore the possibility of forecasting the severity of attack so that growers might be advised whether sprays were likely to be needed or not.

To this end, the correlation of egg numbers and the final pod infestation at harvest was examined. In 1960, samples of 10 plants were taken from the same part of one unsprayed headland on 27 fields once or twice weekly from flowering to harvest and the number and stage of development of all eggs recorded. Some idea of the errors involved in relying on a 10 plant egg sample was obtained by comparing the number of eggs found on 10 lots of 10 plants from the same part of the headland on two sites. The mean number of eggs per 10 plants with their respective standard errors were as follows:- 2.6 ± 0.75 and 25.2 ± 1.9. Samples of 100 pods were taken from the same areas at each of the 27 sites just before harvest to assess pea moth damage and the number of larvae.

The total number of eggs (hatched and viable) per site found over the sampling period ranged from 0-98 (eggs were found on all but one site): the maximum numbers ('peak' eggs) per 10 plants on any one date ranged from 1-36 and the percentage pod infestation on the 27 sites varied from 2% - 52%.

All possible relationships between the egg numbers and final pod infestation have not been analysed but the total number of eggs found at each site and the 'peak' number (hatched and viable) found at any one time have been compared with the number of larvae found and the percentage of pods infested. The best relationship (correlation coefficient 0.9) existed be-

tween the 'peak' number of eggs per 10 plants and the percentage of infested pods. Based on the square root transformation of these variates, the regression equation for the 27 sites in 1960 was:

$$Y = (0.98 \pm 0.1)X + 1.51$$

where (Y = sq. root of % infested pods and X = sq. root of 'peak' no. of eggs per 10 plants)

Using this formula a pod infestation of 10% - 30% could be expected with 10 eggs per 10 plants, at the 5% probability level.

Similar data were obtained for 15 sites in 1961 but on 12 of these, the pod infestation was below 12 per cent. More work is needed to test the formula in other seasons and to examine further possible relationships between egg numbers and pod attack. Further work may show that in some years there will be no clearly defined 'peak' but a continuous level of egg laying. In these circumstances a regression based on 'peak' numbers would probably be of little value.

Again, the degree of attack on the headland is likely to be different from the rest of the field and it may be necessary either to investigate this relationship or to collect larger samples from the field. There is some evidence that pea moth attacks develop earlier on the headlands than on the rest of the field (Franssen, 1954): sampling on the headlands could thus give an extra period of time in which to issue the forecast.

It would clearly be impracticable to apply this method of forecasting for large scale advisory purposes as the quantity of plant material to be examined is not easily coped with. However, it might be possible to obtain forecasts for a limited number of fields in areas where pea moth is known to be a serious pest on dry harvesting peas on which to base more general advice.

Summary

Surveys of pea pests in 1957-59 showed that pea moth was an important pest on dry harvesting peas in East Anglia. It was estimated that on average approximately £100,000 is lost annually through this pest in three of the main pea growing counties. The control of pea moth was unsatisfactory. Trials in 1958 showed that incorrect timing of sprays was one of the main reasons for the poor control and that some knowledge of the date of the moth's emergence and egg laying was necessary to help growers spray at the correct time. Spray warnings based on field observations of moth emergence and egg laying were given to growers in 1959-61.

Chemical control trials showed that even with reasonably good timing of sprays the control was far from perfect and it has been shown that the economics of control measures are not very favourable to the grower. Even on fields where yields are in the region of 23-30 cwt. per acre, infestations of 20 per cent or more are necessary to justify the application of DDT sprays.

Preliminary work on forecasting levels of attack from egg laying has been started and a relationship between 'peak' egg numbers and pod in-

festation has been shown for 1960.

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SESSION IV

CONTROL OF APPLE MILDEW

Chairman: R. W. Marsh
Long Ashton Research Station

THE CONTROL OF APPLE MILDEW

by R. T. Burchill
East Malling Research Station

Podosphaera leucotricha (Ell. and Ev.) Salm. has been known as the cause of apple and pear mildew for approximately 85 years. This fungus, which is now found in all the apple growing districts of the world, attacks young shoots, leaves, fruits and blossom trusses of most commercial varieties. A severe infection on shoots can lead to defoliation, curtailment of growth, and a reduction in the number of fruiting buds formed on the two-year old wood below. Infections of the blossom trusses result in the non-production of fruit; and successive attacks on the same trees will lead to a cumulative loss of crop. Direct attacks on the fruit can cause a form of russeting which reduces its market value.

For many years the disease was adequately controlled, but during the last decade it has become more prevalent. Various reasons for this have been suggested, including changes in climatic conditions; however as the increase has been world-wide, this seems unlikely. Other observers have called attention to changes in spray materials and pruning practices as contributory factors. The increasing importance of apple mildew and the confusion concerning the reason encouraged us to investigate the life history and control of the disease more closely.

Apple mildew is a member of the Erysiphales (the powdery mildews) and, in common with most members in this group, forms two stages in its life history, the imperfect stage, (sometimes called the oidia stage) producing the conidiophores and conidia, and the perfect stage or perithecium. The latter is frequently found but no function has yet been ascribed to it, although in other members it functions as the over-wintering body. Successful perennation depends on the ability of the fungus to invade buds during the summer; once within the bud, the hyphae remain dormant until the following spring when, with renewed host activity, the fungus spreads to cover the emerging leaves, forming the PRIMARY INFECTION. Conidia from these infections are then carried by the wind to healthy tissues giving rise to the SECONDARY or SUMMER INFECTIONS.

Much of the work at Long Ashton was devoted to a study of the perennation of the disease and as most of this has been reported earlier, only a brief summary will be given here. It was confirmed that the sole means of perennation was by mycelium present within diseased fruit and vegeta-

tive buds. Most buds were infected by mycelium spreading from an infected leaf lamina, down the petiole and into the bud. Direct infection of buds by conidia was less common. Infection of terminal buds could occur at any time during the growing season and continued until just after growth had ceased.

Infection of axillary buds was successional, the earlier formed ones being attacked at the beginning of the summer and the later ones at the middle and end of the season. Each bud remained susceptible for approximately one month after emergence, i.e. until bud closure and suberisation of the outer scales prevented infection. For similar reasons fruit buds on dwarf shoots were also susceptible to infection for approximately one month after formation, i.e. during May and June. The fruit buds were the first to open in the spring, and if mildewed, were a source of conidial infection during April and May. The terminal buds opened about three weeks later and, if infected, usually produced extension shoots on which mildewed leaves arose in succession throughout the season. Diseased axillary buds were not an impotant source of infection because they rarely opened or produced only a few mildewed leaves which were soon shed.

Surveying all the sources of infection it is clear that conidia are available as soon as the first leaves unfold and these give rise to secondary infections which in turn provide the inoculum for further spread of the disease. There is thus a continuing supply of conidial inoculum available from bud-burst until autumn defoliation. For most of this period, i.e. mid-May until September, the tree is producing a succession of vulnerable buds, together with a much smaller number of fruit buds which are normally susceptible only in May and June. In favourable weather, therefore, new mildew infections may continue to arise throughout the season.

Control

In controlling mildew, the ultimate objective is to eliminate overwintering stages of the fungus by protecting the buds from infection. Apart from the costly process of cutting-out mildewed organs, there is no established method of preventing conidial formation and control is therefore based mainly on the use of protective fungicidal sprays. It is unlikely that these directly prevent infection of buds for the buds when young are almost entirely enclosed between the stem and the concave face of the petiole which subtends them, and are thus shielded from spray deposition. Terminal buds and fruit buds are in addition densely invested with hairs which adds to the difficulty of providing a protectant covering.

The major effect of the fungicide, therefore, is probably to check the establishment and spread of the secondary leaf infection. As these are the source of the mycelium that invades the bud, via the petiole, control of secondary infection indirectly safeguards the bud. At the same time, it restricts the build-up of conidia which would otherwise be available for spreading the disease to leaves and, occasionally, directly to the buds.

Because of the continuing production of new foliage, and the long period of susceptibility of the terminal buds, it is apparent that spray applications in general do no more than interrupt the flow of infection.

Protection of the fruit buds, which have only a limited period of susceptibility, is more easily timed. This point was demonstrated in 1956/57 and 1957/58 in trials carried out at Long Ashton on Cox's Orange Pippin trees. Eight lime sulphur (at 1%) spray programmes were compared, namely at the stages 1*, 1+2, 2+3, 1+2+3, 2+3+4, 1+2+3+4, 3+4 and 4. Six trees were used for each comparison and there were also six unsprayed trees and six sprayed with dinocap (1 lb per 100 galls) at times 2+3. In 1957 the treatments were the same except that trees sprayed with lime sulphur at stage 1 only received instead dinocap (1 lb per 100 galls) at times 2+3+4.

Results were assessed from the percentage of mildewed trusses in May of the year following treatment. In both years pre-blossom sprays had little effect on the over-wintering potential, whereas the post-blossom sprays reduced infection to less than a quarter of that in the controls. Dinocap at 2+3+4 gave control equal to that obtained with lime sulphur applied at the same times.

The results of this trial indicated the importance of post-blossom applications in reducing fruit bud infections, pre-blossom having little effect. In the 1957-58 trial the effect of the sprays on terminal bud infection was also assessed but there was little correlation between the times of application and the degree of control obtained. It is suggested that this difference is related to the periods of susceptibility of the two types of bud. As noted previously, fruit buds are only susceptible to infection during May and early June, so that sprays at the petal fall and fruitlet stages (applied on the 18th May and 7th June 1956 and the 6th May and 11th June 1957) might be expected to reduce the infection of these buds. Terminal buds, on the other hand, continue development and remain susceptible throughout the growing season; in fact, those infected from July to September constitute one of the main sources of overwintering mildew infection. Obviously no direct protection can be expected at this period from sprays applied in May and June although some indirect control may result from the suppression of secondary infection in the orchard.

The necessity for controlling secondary infections cannot be too strongly emphasised; experiments at Long Ashton showed that almost 90% of the primary infections in the spring of 1957 resulted from secondary leaf infections of the previous year which had subsequently spread to the buds.

Absolute control of these infections is difficult, because of the long infection period. Investigations at the East Malling Research Station have shown that new infections continue to arise throughout the summer, and this year they have occurred as late as mid-September. Late infections of terminal leaves are particularly important as they are responsible for many of the terminal bud infections. (The majority of buds infected at this time appear normal and cannot be distinguished externally from healthy ones.)

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* 1 = green cluster 2 = pink bud 3 = petal fall 4 = fruitlet

If the aim is to control all these infections, then spraying must be continued until the end of the growing season, when closure of the buds affords complete protection. In the Netherlands secondary infections have been effectively controlled and the number of bud infections reduced by approximately weekly applications of half-strength dinocap, extended well into August.

Changes in pruning practices have contributed much to the increase in mildew during recent years. Under the renewal and regulated systems very few extension shoots are pruned, and many apparently healthy terminal buds carrying late season infection escape detection.

In a pruning trial at Long Ashton in January 1958, 24 trees of equal girth and size from two selected plots, were renewal pruned and in addition one inch of each extension growth over six inches long was removed on half of these trees. On all trees, however, obviously mildewed buds and shoots were removed during the pruning. In June 1958 the numbers of mildew infections were recorded. On trees receiving normal pruning the percentage infection of terminal buds ranged from 16-19% whereas on those trees receiving normal pruning plus tipping, the percentage infection was 1.8 - 2.8%.

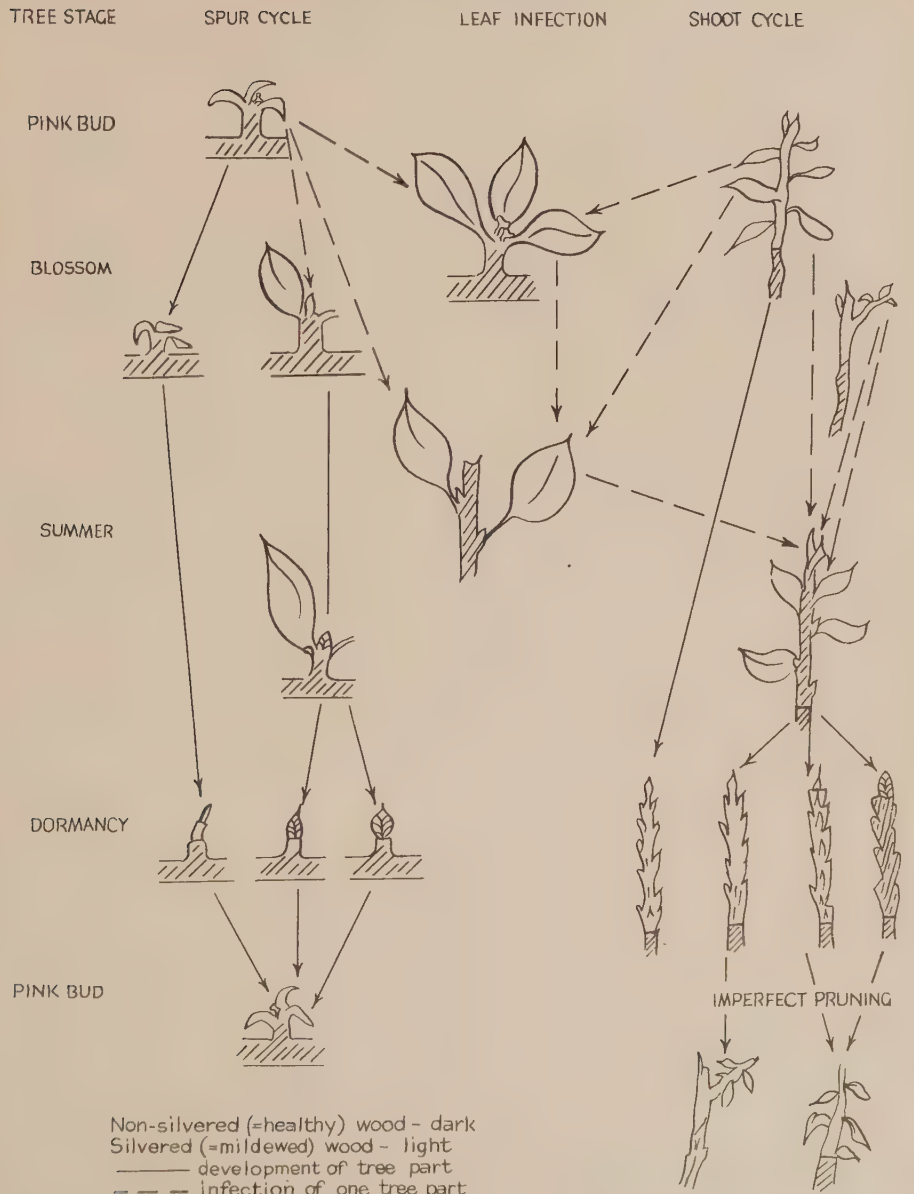
Although effective in reducing primary infections the regular use of this method of pruning would militate against proper tree management and might jeopardise tree shaping and crop production. However, a limited application of the method, or even spur-pruning, might be justified in areas of high mildew intensity.

An alternative control measure is the use of DNC/petroleum sprays applied in March (just before bud burst). M.H. Moore and Miss Bennett (at The East Malling Research Station) during the course of five years' experiments have shown the value of such applications in reducing the number of primary infections in the spring but, as with tip-pruning, this is a control measure to be recommended only in areas of high mildew infection.

A systemic fungicide capable of destroying the perennating mycelium within the buds, would no doubt be the ideal solution to the mildew problem, but until such a fungicide is developed, control must be based on the use of fungicides applied during the growing season.

The need to remove all visible mildewed shoots in winter and diseased blossom trusses and extension shoots in the spring, coupled with an intensive spray programme in the early summer, cannot be too strongly stressed. Not only will this reduce fruit bud infections, but it will also prevent a rapid build-up of the disease at a time when there are so many young susceptible leaves available for infection. A continuation of spraying until the end of the growing season although affording further protection to leaves and terminal buds may not be practical on economic grounds. Finally where control during the summer has not been satisfactory then a tipping of all extension shoots will reduce the mildew to a low level in the following year.

GENERALISED REPRESENTATION OF THE LIFE HISTORY OF APPLE MILDEW



THE LIFE HISTORY OF APPLE MILDEW AND THE FIELD ASSESSMENT OF THE DISEASE

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Summary

The life history of the disease is briefly described and the results of two growers trials are given to illustrate the value of recording mildew on different tree parts for different purposes.

Introduction

Apple Mildew is a complex disease for the fungus can attack all young parts of the tree during the growing season and overwinters in buds. Successful control depends on the wise use of anti-mildew fungicides and pruning methods. Both are essential, and in laying down trials using one, the other needs to be considered.

In trial work the problem of assessing the disease arises, and with apple mildew a choice appears to be available as to which tree part to observe. In spray trials, some workers have assessed secondary leaf mildew only (e.g. Sprague, 1955) while others have favoured primary mildew on the flower trusses the following spring (Hey, 1957). In survey and trial work the author has made six or seven records in the course of three visits per season to each orchard or plot, assessments being made according to the method already described (Baker, 1961). While all were of value in understanding the disease itself, the relative merits of each for different purposes also became evident.

Life history of the disease

The diagram (Fig. 1) shows the development of apple mildew through the season. There appear to be two 'cycles' of infection, the spur and the shoot cycle. One could almost exist independently of the other, but on most varieties of apple, both occur.

The spur cycle

By early pink bud, flower trusses are visible which are abnormal due to the complete coating of mildew spores on all surfaces and consequent malformation of flower parts. The number of such primarily mildewed trusses increases through the blossom period, and infected leafy trusses appear. All these are producing spores which after a few weeks begin to infect young spur leaves, so that some time in the first two weeks of May the first secondary mildew lesions can be seen on the lower surfaces of the leaves. Concurrently, infections occur in the very young buds in the axils of the leaves and also (Roosje, 1959) on the young fruitlets on flower trusses.

As the young spur buds develop, the outer scales harden and the fungus within them is cut off from external influences (among them, fungicides) and can grow freely. The bud continues to develop but if much fungus is present it becomes distorted. By autumn, when the buds are clearly vis-

ible, distorted ones are readily distinguishable from normal ones. Records made in many orchards showed (Baker, in preparation) that in the years 1956, 1957 and 1958, there was a direct relationship between the number of mildewed flower trusses in an orchard in spring and the number of distorted buds seen in autumn. In addition, however, the spurs which carried primary mildew, the soft parts of which dropped from the trees by the end of June, remain with silvered wood and small, distorted buds, and some of the normal looking buds on healthy spur wood may also harbour the fungus.

Any of these three types of bud may give primarily mildewed growth next year but most of the primarily infected buds will die, and most of the normal looking ones will be healthy, the greatest proportion of primary mildew coming from secondarily infected, distorted spur buds. Over the winters 1956-7 and 1957-8, there was a direct relation between the number of distorted buds seen in autumn and mildewed flower trusses seen the following spring.

In this cycle of infection, control is achieved by cutting out the primarily mildewed trusses at pink bud, and spraying during the blossom period to protect the young leaves, spur buds and fruitlets.

The shoot cycle

During blossom, buds on shoots produced last year, and those previously dormant on older wood, begin to grow. Some may have contained the fungus, and so produce completely mildewed tissues in the form of young shoots, spurs, a few leaves only, or, occasionally, flower trusses. These represent an additional, abundant source of spores. Whereas the 'infectors' in the spur cycle have generally died by midsummer, these may continue to develop for a longer period and, in the case of young shoots, often until growth ceases in autumn.

Spores from all primary and secondary mildew sources infect young spur and shoot leaves to give lesions on the lower surfaces, young buds on otherwise healthy shoots, and growing points of shoots (when all subsequent growth is completely mildewed). If a shoot is infected as its seasonal growth is finishing it may have only terminal bud infection.

In the shoot cycle of infection, control is achieved by spraying from blossom time onwards to prevent secondary infection of leaves, shoots and buds and pruning in winter to remove mildewed areas of shoots and terminal buds. Some primary infection may be evident at the time of spring pruning and can be removed then.

With the life cycle in mind, the effects of various treatments can be studied.

Effect of previous year's spraying, tipping in winter and late spring pruning

In 1956 in a large Essex orchard of Cox's Orange Pippin trees on type II rootstock, assessments were made on four sections which had been treated similarly except for three factors. In 1955 the grower had applied

a programme of three mercury and three captan sprays to one section, whereas the rest of the orchard received two pre-blossom and two post-blossom sulphur sprays. In the sulphur area, tipping of leader shoots was carried out in winter 1955-6 in one section, late spring pruning when young shoots were developing in another, and no such treatment in the third. The results are shown in Table 1.

Table 1 Mean percentage mildew on four occasions in an Essex orchard with four different treatments

Date of observation	Part of tree mildewed	1955 No sulphur	1955 Sulphur		
			Tipped	Not tipped	
			No spring pruning	Late spring pruning	No spring pruning
25.5.56 (full blossom)	Flower trusses	16.2	-	3.6	4.4
	1955 shoots	97.0	-	30.0	46.0
11.7.56	Leaves on spurs	0.6	0.1	0.3	0.6
	" on shoots	15.4	7.9	2.3	7.3
8.10.56	1956 shoots	92.0	45.0	14.0	41.0
	Distorted spur buds	11.2	6.8	3.4	3.4
2.5.57 (full blossom)	Flower trusses	*4.0	-	-	3.4

* spring pruned before recording

The trial was not replicated and the results not analysed statistically, but it serves to illustrate the following points:-

1. For the effect of previous years' spraying, records at blossom time of mildew on both flower trusses and 1955 shoots were of value. By mid-summer, the 1956 spray programme was having an influence, but differences between non sulphur and sulphur sprayed sections were maintained throughout the 1956 season.

2. For the effects of tipping in winter, a spring count was not available: mildew on the 1955 shoots in the tipped section could not be recorded since cut shoots were not susceptible of examination. Tipping mainly affects the shoot cycle, and the percentage 1956 shoots affected in autumn was of greatest interest. In this instance, no difference was apparent between tipped and non tipped control sections. This was probably due to the marked necrogenous effect of mildew in this orchard - a good deal of bud death and shoot dieback occurred in all sections, and in the sulphur area only 3-5% completely mildewed shoots developed in 1956 even in the non tipped sections - infector shoots which might have been responsible for increased secondary leaf and young shoot infection. There were 10%

completely mildewed shoots in the no sulphur section.

3. For the effects of late spring pruning, the results of most value were those on shoot leaves in midsummer and 1956 shoots in the autumn. The operation was done too late to influence the infection of young spur buds, and affected the shoot cycle most of all.

Effects of current season's spraying and early spring pruning

In 1957 in a Suffolk orchard of Cox's Orange Pippin trees on type II rootstock, assessments were made on eight sections. The grower applied four different anti-mildew spray programmes, with one replication of each. All sprays were applied at normal commercial rates on the same dates, but materials used at pink bud and blossom or from mouse ear to early fruitlet varied: before and after this they were either lime sulphur or wettable sulphur. Within each of one set of four sections, no anti-mildew spring pruning (4 trees only) and very thorough pruning (4 trees only) were compared with commercial pruning at pink bud (rest of section). The results are shown in Table 2.

Table 2 Mean percentage mildew on four occasions in a Suffolk orchard with seven different treatments

Date of observation	Part of tree mildewed	Spray treatments (Commercial pruning)				Spring pruning (all spray treatments)		
		Sulphur throughout	Dinocap pink bud and blossom	Dinocap mouse ear to fruitlet	Dinocap plus sulphur pink bud and blossom	None	Commercial	Thorough
7.5.57 (full blossom)	Flower trusses	2.3	2.1	2.4	2.7	12.3	2.4	0
	Leafy trusses	15.5	-	-	21.8	18.0	18.7	0
18.6.57	*Leaves on shoots	26.5	18.3	14.3	7.2	19.0	15.8	16.7
	1957 shoots	11.9	10.0	10.0	4.4	16.3	11.3	6.3
11.10.57	Distorted spur buds	3.9	2.0	1.4	3.0	8.0	1.9	1.3
1.5.58 (early blossom)	Flower trusses	1.9	0.8	0.3	0.8	2.0	1.0	0.7

* Topmost 14 leaves on eight leading shoots per treatment examined for secondary lesions.

1. For the effects of current season's spraying, affecting both the spur and the shoot cycle, the shoot leaf, shoot, bud and flower counts were all of value. It is worth noting, however, that whereas for shoot leaf and shoot records, the two dinocap treatments had similar effects, with dinocap plus wettable sulphur being rather better, all the treatments containing dinocap were similar for bud and flower infections, and somewhat better than the all-sulphur programme.

2. For the effects of spring pruning here, the shoot, bud and flower figures were of more value than the leaf counts, the shoot and bud counts showing clear differences.

In this orchard, a commercial preparation containing DNC was used just before bud burst in 1958, and whether or not this influenced the proportion of flower trusses appearing which were mildewed could not be determined: but in fact rather less than one half of the amount of flower trusses were mildewed in spring than spur buds distorted in the autumn, and the bud records gave more recognisable differences.

Discussion

A case can be made out for using each one of the six different records for mildew, and others, such as leafy trusses in spring or even fruit russetting at harvest, can be added. No generalisation can be made as to which are the best to use, as requirements for trials differ. In a single trial, leaf assessments may well be of value. Where several orchards are to be compared with each other in any one season, leaf assessments are less reliable as they cannot always be done on the same day or even within the same week. For this type of work the more 'static' counts of distorted buds (which can be done any time from late summer to just before bud burst) or shoots (from the cessation of growth until winter pruning time) or flower trusses (pink bud to spring pruning time - a rather shorter period) are probably more reliable.

In conclusion, experience in survey and trial work has shown that the complexity of the apple mildew disease is such that the most valuable information is gained when assessments are made on more than one occasion and on more than one tree part.

Acknowledgements

Grateful thanks are expressed to members of the Plant Pathology Department at Cambridge, and to N.A.A.S. Horticultural Officers Mr. A.D. Todhunter and Mr. R.W. Rennison, who all assisted with the assessments; and to the owners of Spring Grove Orchards Ltd., West Bergholt, Colchester, and Mr. C.R. Thompson, of Risby Fruit Farms Ltd., Risby, St. Edmunds. The author also wishes to thank Mr. W C. Moore, Director of the Plant Pathology Laboratory, Harpenden, for providing accommodation and facilities for preparing the apple mildew work for publication.

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WINTER AND SPRING PRUNING AGAINST APPLE MILDEW

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Summary

Trials and shoot observations have shown that particular attention is needed to the position of the cut when pruning shoots in the winter, and that timing is important when removing mildewed flower and leaf trusses in spring.

Introduction

The fungus causing Apple Mildew, Podosphaera leucotricha, is a very successful parasite. Once it becomes established within developing buds it is locked away from potential destruction. Thus once a neglected apple tree has been attacked, infection is likely to remain on it indefinitely, unless all the infected buds are destroyed in a severe winter, which seems to be a rare occurrence in this country.

The two main means of controlling the disease at present are: (a), the application of suitable fungicides to prevent infection or to arrest it in the early stages of development and (b), the excision of invaded buds either when dormant (i.e. those on shoots) or a few weeks after bursting (i.e. those on spurs). This paper is concerned with the latter.

Winter pruning of the one year old shoots is an accepted practice in commercial orchards of certain varieties of apple and mildew infection can be cut out at this time. Pruning of the spurs at blossom time is rarely done for any other purpose than to remove mildew infection. It is important to know, for winter pruning, which parts of attacked shoots need to be removed, and for spring pruning, at what time the operation can best be done. Observations made in various orchards in East Anglia, all on the variety Cox's Orange Pippin, are described to illustrate these points.

Winter Pruning

Invaded buds on shoots formed in the previous season may occur either on silvered wood, that is, wood which developed from mildew infected growing points during the growing period, or on non-silvered, healthy wood. When on silvered wood, distorted buds occur consecutively along the shoot, whereas on 'non-silvered' wood they tend to be scattered, since each invaded bud represents a separate infection whether by mycelium or by spores. However, observations on one hundred marked shoots in each of four orchards in 1958 indicated that the first three buds immediately behind a silvered area were more likely to break in a mildewed condition than those more widely separated from the silvered area: also that on a healthy looking, non-silvered shoot, the first five buds (including the terminal bud) were more likely to break mildewed than any others. This result is detailed in Table 1. Dead and dormant buds were not included in the calculations.

Table 1 Percentage of growths showing primary mildew developing from buds on 1957 shoots in May 1958

Orchard (Parish and County)	Date of examination and tree stage	Non silvered shoots		Silvered shoots		
		Up to 5 buds from tip	6th bud to base of shoot	Within silvered area	Up to 3 buds below silvered area	From 4th bud below silvering to base of shoot
Burlingham (Norfolk)	May 15th Late blossom	5.8	0	19.8	4.9	0
Orwell (Cambs.)	May 6th Early blossom	8.9	1.7	16.7	11.7	0
Wisbech St. Mary (Cambs.)	May 15th Late blossom	14.9	3.0	17.9	18.8	4.6
Bradfield St. Clare (Suffolk)	May 9th Full blossom	16.5	0	26.8	11.3	4.2

Midsummer and post harvest recordings indicated that a good deal more primary mildew showed up after the blossom time observations. Some of the mildewed growths dropped from the trees however, so that by the end of the season much the same amount of primary mildew was visible as in May. A primarily mildewed growth took the form of a shoot, a dard, a spur, or perhaps only one or two leaves and a bud on the 1957 shoot. Of the mildewed shoots which developed, all came within the range of five buds from the tip of a non silvered 1957 shoot or up to three buds beyond the silvered area of a mildewed 1957 shoot.

These findings were used in two ways in 1959 and 1960. In a three year replicated pruning trial begun in 1958, the shoots of treated trees were pruned in such a way that when tipping, the topmost five buds were removed and when cutting silvered shoots, the cut was made between the third and fourth bud below the silvered area.

In shoot development observations on 330 shoots in one orchard in 1959, pruning by this method was compared with pruning away only obviously distorted terminal buds and silvered parts of shoots, and with unpruned shoots. It is worth noting that in the pruning trial, a rather better control was effected in 1959 and 1960 using this method, than by the less precise pruning done in 1958, and that in the shoot observations, this method was preferable to that where only obviously mildewed growth was removed.

The pruning trials, in addition, showed that there was no carry-over of any effect of winter pruning from one year to another. This is shown in Table 2, where the figures for primary shoot mildew on one year shoots have been converted to square roots and analysed statistically.

Table 2 Mildewed shoot production on one year shoots on trees with silvering plus tips removed compared with untreated trees.

Orchard (Parish and County)	Experimental pruning was -			
	for the first time	for the second time	residual from 1958	
			in 1959	in 1960
Orwell (Cambs.)	-1.40* ±.37	-1.38* ±.34	.00 ±.62	-.71 ±.47
Wisbech St. Mary (Cambs.)	-1.50* ±.38	-1.46* ±.62	-.75 ±.58	-1.23 ±.81

In practice it appeared that although mildew carried in shoot buds from infections the previous summer could rarely be eliminated, it could be substantially reduced by careful winter pruning, but that this operation needed carrying out every year, as the benefit in summer from doing it the previous winter was probably not carried over to the summer after next. It is worth adding that with the more precise methods employed, no more time seemed to be taken than with more haphazard methods of riddling the trees of mildew. However, the recognition of silvering, on which the method depends, is easier when the shoots are dry rather than when soaked by rain, dew or mist.

Spring Pruning

In a survey of Cox's Orange Pippin orchards in East Anglia from 1956-8, it was found that about half of the growers whose orchards were recorded for mildew had removed mildewed trusses during the blossom period. The cost per acre of this operation varied, but for three growers who supplied estimates it ranged from £10 to £20 on established trees, and a fourth grower, having reduced mildew by other means in addition, recorded a drop from £18. per annum in 1957 to £3 in 1958 in one of his orchards.

Observations made on 10 occasions from bud burst onwards in 1957 on 55 marked spurs on Cox's Orange Pippin trees in an orchard at Coton, Cambridgeshire, showed that primary mildew was apparent from green cluster onwards, reaching a maximum by blossom time in the floral buds and petal fall in the vegetative buds. Spur tissues could appear healthy after bursting for up to four weeks before showing characteristic symptoms of primary mildew. By early pink bud approximately 50 per cent of the total primarily mildewed trusses had shown up.

Such information as this might indicate that removal of primarily mildewed trusses could best be done at blossom time. However, in some seasons, secondary mildew has appeared by this time. This trend is illustrated by details for four seasons in Table 3.

Table 3 Flowering periods on Cox's Orange Pippin trees in East Anglia from 1956-9 and dates of first observation of secondary mildew on leaves

	Pink bud	Petal fall	Secondary mildew
1956	April 23rd - May 16th	May 23rd - June 1st	May 11th
1957	April 10th - 25th	May 4th - 22nd	May 15th
1958	April 30th - May 5th	May 12th - 27th	May 13th
1959	April 18th - 26th	May 11th - 19th	May 11th

Thus in many orchards secondary mildew first appears after pink bud, and before petal fall.

Observations on the effects of spring pruning in survey orchards and in growers trials have led to the conclusion that the most advantageous time to carry out spring pruning is before full blossom. Primary mildew will appear after this in the form of flower and leaf truss mildew, and a few growers are able to go over the orchards a second time: but even where mildew is serious, one attempt at removing the primary sources of infection may well be of great benefit. Reference to Table 2 in the previous paper (p.176) shows, in the spring pruning section, that commercial pruning, done in mid-April (pink bud), gave satisfactory reduction of distorted spur buds, while thorough pruning, also done in mid-April, but again May 1st to 8th (late blossom) gave little or no better reduction of distorted spur buds, yet appeared to be associated with a reduction of secondary mildew in the young shoots.

Discussion

Evidence given by various workers (Kosswig, 1958, Burchill, 1958) emphasises the importance of tipping to remove overwintering shoot infection. The author's observations support this, and in addition suggest that when cutting silvered shoots from the trees, a short piece of non-silvered wood behind the silvered area should also be removed. Neither tipping nor silvered shoot removal is, however, practicable on large trees of culinery varieties such as Bramley's Seedling. If shoot mildew becomes a problem on them, the most suitable control measure would probably be to spray towards the end of the growing season with a fungicide such as dinocap to prevent infection of the shoot tips.

Removal of mildewed flower trusses is often advocated, and practised, but it is not known at present above what level of infection this is advisable. It may be, for instance, that at levels below 2 per cent, the operation becomes unnecessary, because other sources of mildew are later available and may even be more potent than this. Certainly, at 5 per cent, flower truss mildew begins to look quite serious on a tree, and many growers who normally consider spring pruning, would do so. Again 2 per cent in an isolated orchard may be worth removing to keep the disease in check, whereas 2 per cent in an orchard in an intensive apple growing area may not be. This matter needs further examination.

Finally, while this paper refers only to removal of existing infection, mention should be made of the infection process itself. Research workers in the past have studied the infection conditions required for leaf infection. If a study could be made of the requirements for young bud infection, and infection of the very susceptible tips of growing shoots, progress might be made towards recommendations for spraying when infection conditions obtain, so that pruning away established infection becomes less necessary. It may well be that there are only a few days in the whole of the growing season when conditions are suitable for widespread bud and growing point infection.

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THE IMPORTANCE OF SHORT TIME INTERVALS BETWEEN SPRAYS AGAINST APPLE POWDERY MILDEW

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Introduction

Apple powdery mildew is nowadays considered to be the predominant fungus disease in apple culture in the Netherlands. The disease has been known for many decades, but did not cause excessive damage before about 1950.

A factor that could be responsible for the increased importance of the disease since about 1950 is the strong expansion of the very susceptible variety Jonathan after 1945 on which mildew overwinters more readily than on most varieties. Another factor, which is certainly also responsible for the increased incidence of mildew after 1950 is the change from inorganic sulphur compounds for scab control to the organic fungicides, such as organic mercury compounds, ziram, thiram, 2,4-dinitro-thiocyanobenzene and captan, which meant a change from fungicides active against apple mildew to fungicides not or only slightly active in this respect.

It is possible that more virulent strains of the causal fungus have arisen in the last decade, but there is no evidence to support this possibility.

Since apple mildew became a major problem on susceptible varieties investigations on this disease have been intensified in many countries including the Netherlands.

The purpose of the investigations carried out in the Netherlands was to gain more information regarding the conditions favourable for mildew infection and also to improve mildew control by spraying according to critical phases in the development of the fungus.

Damage by apple mildew

On shoots and leaves

In 1959 mildew damage was assessed on Jonathan trees on which no mildew control had been practised in that year. It was found that the leaves formed between May and the middle of July had 55% of the undersurface covered with mildew; by 23rd July 36% of the long shoots were overgrown by the fungus and at the end of the season 98% of the terminal buds of the long shoots were infected. It was also found, that the length of long shoots on trees heavily infested with mildew was 18% less than on trees with only a light attack.

On quantity of fruits

Our own experiments and those of other Dutch investigators show, that the loss of crop in the year in which a severe mildew attack occurs for the first time varies from 0 - 20%. Müller (1957) also reported no influence of severe mildew attack of the leaves on the yield in the first year. But in years following a serious attack, more severe losses have been reported.

In a particular experiment the average yield per tree in 1959 of Jonathan on M IX, which had not been sprayed against mildew in 1958 and were therefore seriously attacked, amounted to 5,4 kg, whereas comparable trees which received 12 sprays (4 times o,5% of a proprietary mixture of wettable sulphur and captan followed by 8 times 0,12% Karathane WP*) against mildew, yielded 18,7 kg per tree. All the trees were treated uniformly in the season 1959. So this experiment showed a reduction in yield of about 70% as a result of a severe mildew attack in the previous season.

Uitterlinden (1960) also reported 45% reduction in yield in 1959 of Jonathan on M IV not sprayed against mildew in 1958 in comparison with trees treated 8 times with 0,12% Karathane WP.

A third experiment reported by Immikhuizen and van der Waal (1961), showed 75% reduction in yield on Jonathan trees, where removal of the overwintered infection and spraying against mildew had been omitted in the previous season. In a fourth experiment reported on by the same authors, a reduction in yield of about 30% resulted on unsprayed trees in comparison with trees, which were sprayed 15 times with 0,06% Karathane WP in the previous season.

These Dutch data agree very well with data published by Müller (1957) for the variety Krügers Dickstiel. He reported that trees not treated against mildew in 1952 had about twice as much mildew attack as trees treated in that year, which resulted in 1953 in 63% reduction of the yield. Trees which were not sprayed in 1952 and 1953 showed an 84% reduction of yield in 1954. In Hungary Czorba (1956) found in three experiments on Jonathan, that a severe mildew attack in 1954 reduced the yield in the next year experiments respectively by 43%, 51% and 57%.

On quality of fruits

Mildew attack of the fruits of some pear varieties, especially Doyenne du Comice, is well-known, but is not often serious. The mycelium and later in the season also the perfect stage of the fungus can easily be detected on the skin of pears, even when the fruits approach maturity. Cunningham (1923) reported that apple mildew caused a brown or yellowish russeting on the fruits of some apple varieties in New Zealand. A weblike russeting on Jonathan fruits has also been recognised as due to mildew by Sprague (1955) reporting from the western fruit growing area in the U.S.A.

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* Karathane WP is a formulation of dinocap and contains 22,5% 2-(1-methylheptyl)-4,6-dinitrophenyl crotonate and 2,5% dinitrocapryl phenol.

The mildew fungus does not persist on the Jonathan apple fruits until maturity as it does on pear fruits. Sprague (1955) stated that infection of the ovary at pre-bloom period resulted in a fine expanded webbing of the mature fruit; he could reduce the percentage of fruits with weblike russeting by early sprays against mildew from 41% in unsprayed trees to less than 10% and in one case even to less than 1% in unsprayed trees.

Our trials, summarised in Table 1, demonstrate also, that the occurrence of weblike russeting of Jonathan fruits can to some extent be prevented by early sprays against apple mildew. The 1959 trial proved that in this year only the sprays applied before 11 May, i.e. before petal-fall, were effective in preventing russeting. The results of the 1960 trial indicated, that the period between 29th April and 9th May, i.e. the blossom period, must have been highly conducive for the occurrence of this type of russeting.

Table 1 Russeting of Jonathan apples by apple mildew

Trial in year	Sprays against apple mildew	Period of sprays	Percentage of fruits with weblike russeting	
			on M IX	on M XVI
1958	4 x 0,5% Compound A* and 8 x 0,12% Karathane WP	1 May - 13 August	5,7	9,3
	None	-	18,0	27,2
1959	14 x 0,06% Karathane WP	20 April - 21 July	25,4	19,0
	4 x 0,06% Karathane WP	20 April - 11 May	18,6	13,4
	4 x 0,06% Karathane WP	11 May - 2 June	36,8	44,5
	None	-	46,3	39,8
1960	6 x 0,5% wettable sulphur and 10 x 0,12% Karathane WP	23 March - 16 August	11,8	
	2 x 0,5% wettable sulphur and 10 x 0,12% Karathane WP	29 April - 16 August	13,9	
	1 x 0,5% wettable sulphur and 10 x 0,12% Karathane WP	9 May - 16 August	25,0	
	None	-	24,1	

* Compound A is a proprietary mixture of wettable sulphur and captan.

The results of several experiments carried out in the Netherlands agree very well with those obtained by Sprague, although the reduction of russeting obtained was generally less.

The damage of mildew to quantity and quality of the production as shown above will justify even expensive control measures, though the growers are often unaware of the damage that mildew can cause.

The next paragraphs will deal with observations made and the experiments undertaken for the purpose of improving knowledge of the biology of fungus.

Observations on the weather conditions favourable for infection by apple mildew conidia

Hammarlund (1925) considered dry conditions to be favourable for the production and spread of the conidia. Yarwood (1957) expressed the opinion that mildew conidia do not require humid conditions for germination and infection, though Fisher (1956), Berwith (1936) and Stoll (1941) held the opposite point of view on apple mildew.

Nover (1957) working on powdery mildew of wheat and barley found that low atmospheric humidity did not stop germination, - possibly because of the high water content of mildew conidia - , but he ascertained a much better germination and rate of infection at a high relative humidity (RH).

In March 1956 some Jonathan trees on M IX, about six-year old, severely infested with mildew, were planted in an open place at about 1 km from the nearest apple trees. 128 two-year old heavily pruned Jonathan trees were then planted in five concentric circles around the source of infection. The 128 trees were planted in such a way that the field could be divided in 16 sectors with 8 trees each. The diameter of the field was about 20 metres (66 feet). Around the field a poplar windscreen was planted, which was not allowed to grow higher than 3 metres (10 feet). Temperature-, humidity-, and wind direction recorders were placed in or near the observation field.

During the growing seasons of 1956 up to 1959 the numbers of newly infected leaves per tree in the different sectors were counted almost daily. At the same time the infected leaves were removed from the field. The results of the counts are summarised in Table 2.

Table 2 Mildew counts in circular experimental field in 1956 up to 1959

Year	Period of mildew counts	Number of days in the check period	Number of counts	Number of days on which mildew was found	Peaks of attack on the dates
1956	24 May - 31 August	100	83	82	29/6, 12-15/7, 27/7, 17-18/8
1957	17 May - 5 September	112	93	92	18-19/6, 23-26/7
1958	19 May - 22 August	96	79	79	29-31/5, 7/6, 17/6-21/6, 26/6
1959	12 May - 18 August	99	83	80	24-28/5, 2/6, 9-10/6, 24/6, 16/7

It is evident from Table 2, that newly attacked leaves were found almost every day after the first lesions appeared. The first new mildew spots on Jonathan on untreated trees in a commercial orchard were found in 1956, 1957, 1958, 1959 and 1960 on 24 May, 4 May, 14 May, 4 May, and 25 April respectively.

The total numbers of infected leaves of all the peaks of attack in a given year and the total numbers of infected leaves on all other days are assembled in Table 3.

Table 3 Data obtained from the circular mildew experimental field from 1956 till 1959 inclusive

Year	Period of count	Number of peaks of attack	Total number of leaves found attacked in peaks of attack A	Total number of leaves found attacked on other days B	Ratio B : A
1956	24 May - 31 August	4	346	1025	3,0
1957	17 May - 5 September	2	593	1943	3,3
1958	19 May - 22 August	4	991	1770	1,8
1959	10 May - 18 August	5	1324	3127	2,4

The data of Table 3 indicate, that the sum total of all leaves attacked during peaks of attack has been less than the attack on all the other days together. This does not seem very promising for the development of a control programme based on spraying according to meteorologically defined infection periods. (See paragraph 3).

The correlation* of peaks of attack and meteorological data recorded 7 - 10 days previously suggests that a period of rather warm and dry weather followed by a period of high RH favours the occurrence of infection by apple mildew conidia.

Accordingly we set up the working hypothesis, that favourable conditions for apple mildew development prevailed when at least one day with high RH (above 80% at 10.00 a.m., 1.00 p.m. and 4.00 p.m.) followed one or more days with low RH (less than 70% at 10.00 a.m., 1.00 p.m. and 4.00 p.m.).

Attempts to control apple mildew by spraying according to specific weather conditions

Aerts and Soenen (1955) concluded from their observations in the field and from the results of artificial inoculations, that infection can only take place at temperatures higher than 20°C. They considered a temperature exceeding 20°C to be the main factor for mildew infection to succeed.

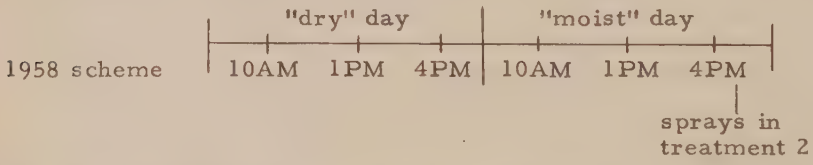
* I am indebted to Dr. J.J. Post, formerly attached to K.N.M.I. for his help in interpreting the observations.

Berwith (1936) observed infection by conidia at temperatures between 13°C and 25°C. Müller (1957) also proved that infection can occur at temperatures below 20°C. Our own observations made in the circular experimental field described above showed for instance, that new mildew spots appeared almost every day between 7 June and 29 June in 1956, although the daily maximum temperatures, measured in a meteorological screen, remained between 13°C and 17°C, and only on three occasions exceeded 15°C. In 1961 the first new mildew spots were found on Jonathan on 25 April though only on 6 April did the maximum temperature rise above 20°C, a temperature was not reached again until 5 June; but on 5 June unsprayed trees in commercial orchards had already developed a severe attack of mildew. We must conclude that in our country mildew infections can occur at temperatures below 20°C.

In 1958 three field experiments on Jonathan were designed to test the validity of the working hypothesis mentioned above, in co-operation with the Plant Protection Service, Division Utrecht and the Horticultural Advisory Service at Barendrecht, who carried out two of the three experiments. The Royal Netherlands Meteorological Institute provided the requisite weather data.

The different treatments and the results of one of these experiments, carried out at Wilhelminadorp, are given in Table 4.

The sprays in treatment 2 were carried out in the afternoon of the moist day as indicated by the scheme:



No sprays were applied in treatment 2 when critical conditions occurred within 8 days after the previous spray.

Table 4 Mildew control experiment at Wilhelminadorp, 1958

Treatment *	Number of sprays	Percentage of leaves attacked **
Spraying at regular intervals of 8 - 10 days	12	14
Spraying at the end of a "moist" day after a "dry" day ***	5	50
No mildew spray	0	80

* 0,5% of a mixture of captan and wettable sulphur was used in sprays up to 30 May, after this date 0,12% Karathane WP.
** Average of 5 counts on different levels of the long shoots.
*** Applications were made on 30 May, 20 June, 2 and 16 July, and 4 August.

It appears from Table 4 that the 5 directed sprays in treatment 2 were less effective than the 12 sprays applied irrespective of the weather conditions. The results of the other two experiments carried out in 1958 agree fully with the results of the experiment at Wilhelminadorp. A possible explanation for the insufficient control by treatment 2 could be found in lack of curative action because the fungicides were applied at the end of the moist day, i.e. the supposed infection day. Accordingly a different scheme was followed in two trials, carried out in 1959. The treatments and the results are given in Table 5, whereas the scheme below shows when the sprays in treatment 2 and 3 were applied.

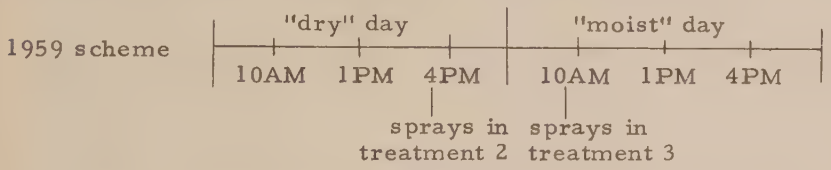


Table 5 Mildew control experiment at Wilhelminadorp in 1959

Treatment (with 0,06% Karathane WP)	Number of sprays	Percentage of leaves attacked *
At regular intervals of 7 days	14	20
On afternoon of a "dry" day	12	22
On morning of a "moist" day after a "dry" day **	3	55
No mildew spray	0	65

* Average of 3 counts on different levels of the long shoots.
** Applications were made on 16 May, 26 May and 26 June.

It appears from Table 5 that the third treatment was totally inadequate though sprays were applied earlier on the supposed infection day than in 1958. Treatment 2 was as good as regular spraying, doubtless because the season of 1959 was exceptionally dry. Indeed the number of sprays applied in treatment 2 approached that of treatment 1.

The results of the second experiment carried out in 1959 by the Plant Protection Service, Division Utrecht, agreed with those of the trial at Wilhelminadorp.

The probable explanation of the inadequate results of the few directed sprays has to be sought in the ratio B : A of Table 3, indicating that the combined effect of many little infection periods is more important than that of 2 to 5 infection peaks.

The idea of a schedule of sprays directed to favourable weather conditions for infection was accordingly abandoned.

Further study of the temperature and humidity requirements for germination of apple mildew conidia

In 1957 and 1958 J.J. Post (formerly attached to K.N.M.I.) carried out many experiments on the temperature and humidity requirements for germination of and resulting infection by mildew conidia. He used saturated solutions of different salts to maintain specific humidities of the air of desiccators provided with circulating fans. Shoot ends (2 to 3 leaves) of Golden Delicious were placed in tubes with water in the desiccators immediately after inoculation of the shoot ends.

It appeared from experiments carried out by this method that infection can occur at all the tested humidities, i.e. 90%, 84%, 69%, 48%, and 40% RH.

In 1958 and 1960 inoculation experiments were carried out at Wilhelminadorp with potted M II and MM 111 rootstocks reared in a greenhouse, to investigate further the range of temperature and humidity conditions under which infection by mildew conidia can occur. Inoculation was effected in 1958 by shaking mildewed shoots above the plants. In 1960 the plants were inoculated in a way similar to that described by Kirby and Frick (1960). The plants were brought into a conditioned room one hour after inoculation. In the experiments from 1958 infection resulted at:-

15,5° C and 55% RH	20° C and 54% RH
16° C and 79% RH	20,5° C and 71% RH
18,5° C and 54% RH	21° C and 82% RH

In the experiments during 1960 infection was successful at:-

11° C and 80% RH	20° C and 42% RH
15° C and 40% RH	20° C and 80% RH
15° C and 80% RH	20° C and 98% RH

These experiments show, that infection can occur under widely varying conditions of temperature and relative humidity, though it should be borne in mind that these are greenhouse experiments (see section 6). The most striking feature, which indicates the difference in behaviour of apple mildew on greenhouse grown and on outdoor apple leaves is the fact that on outdoor leaves the attack is limited to the under surface, whereas the attack on greenhouse leaves is mainly confined to the upper surface.

These laboratory studies, like those of the circular field give no hope for effective control by spraying according to specific weather conditions.

It may be concluded from sections 2 and 4 that the young leaves have to be covered permanently with a protective layer of a suitable fungicide if mildew infection is to be prevented. Now the question remains how long the intervals between sprays should have to be to meet this requirement.

Determination of the maximum effective intervals between sprays against apple mildew

Redistribution of fungicide from older leaves to younger leaves occurs mainly through rainfall. Constant coverage of the younger leaves of growing shoots can in a rainless period only be attained by frequent spraying, because the growing shoots develop new leaves every few days.

From their field trials Groves, Wampler and Lyon (6) drew the conclusion, that the most efficient way to utilise a mildew fungicide (Karathane WP) is to apply small amounts at frequent intervals. According to one of their trials spraying once a week with 0,03% Karathane WP was equal in effectiveness to spraying once in two weeks with a concentration between 0,09% and 0,12% Karathane WP. In a second experiment 0,03% Karathane WP once a week had about the same effect as 0,09% Karathane WP once in two weeks, whereas 0,03% Karathane WP once a week in their third experiment resulted in better control than even 0,12% Karathane WP once in two weeks.

Sprays against apple mildew were in the Netherlands originally applied with 10 - 14 days or even longer intervals. Many mildew control experiments were carried out in the Netherlands by official institutions in which 0,1 - 0,12% Karathane WP was applied at 10 - 14 day intervals, whereas also many experiments were undertaken in which 0,06% Karathane WP was applied at 7 day intervals. Although a direct comparison of the schedules was not made in official experiments, the indications were that a better control was obtained, with sprays with 0,06% Karathane WP at one week intervals than with 0,12% Karathane WP at two week intervals.

Although spraying every week with 0,06% Karathane WP or a low concentration of sulphur compounds can reduce mildew attack to a level probably economically unimportant, the results are in fact unsatisfactory, for it appeared from many experiments, that 10% to 30% of the leaves of Jonathan are infected even when the trees were sprayed every week with a suitable fungicide. In 1959 two field trials were conducted to investigate whether the degree of control reached with weekly sprays could be lowered by spraying two to three times per week. The results of one of these trials are summarised in Table 6.

Table 6 Control of apple mildew with 0,06% Karathane WP at different intervals

Total number of sprays between 20 April and 21 July (13 weeks)	Count* 13 May % infected leaves	Count* 10-15 June		Count* 16-17 July	
		% infected leaves	Rating**	% infected leaves	Rating**
14	5,9	32,3	28,1	23,1	21,0
34	1,7	0,7	0,4	0,9	0,5
0	40,4	75,1	243,3	78,7	139,3

* In each count leaves of different levels of the shoots were examined.
** Rating means: % infected leaves x % coverage of under-leaf surface of infected leaves, divided by 10.

It appears from Table 6 that near perfect mildew control was attained by spraying two to three times per week. Apparently constant coverage of newly expanded leaves had been reached. But of course such a tight schedule of sprays presents insuperable practical difficulties. Fortunately it is probably unnecessary from an economical point of view to get a better control than the level which is reached by weekly sprays. But the trial shows again the importance of short time intervals. The second field trial with short intervals, carried out by the Plant Protection Service, Division Utrecht gave similar results Immikhuizen and Waal, (1961).

Since many fruitgrowers operate automatic mist blowers or speed sprayers, spraying is no longer considered an arduous task. Hence, spraying every week between pink bud stage and the end of extension growth with a suitable fungicide in low concentration could be recommended officially in the Netherlands as a practical system to control apple mildew.

The curative action of mildew fungicides

It appeared, in 1960, from inoculation experiments on potted seedlings reared in a greenhouse at Winchester Fruit Research Laboratory, U.S.A.*, that 0,06% Karathane WP exerted an effective curative action, even when applied 86 hours after inoculation. Further experiments on potted apple rootstocks at Wilhelminadorp in 1961 showed complete curative control of mildew by 0,03% Karathane WP applied 48 hours after inoculation. The experiments also suggest a curative action of 0,25% and 0,04% wettable sulphur if applied 24 hours after inoculation.

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* The author stayed at Winchester Fruit Research Laboratory, Winchester, (Virginia), U.S.A., from April - July 1960, mainly to carry out research on apple powdery mildew. He is indebted to Dr. A.B. Groves, plant pathologist at forementioned laboratory, for his useful suggestions.

In the orchard, the practical importance of the curative action of Karathane WP and wettable sulphur does not appear to be great for complete control can only be obtained by spraying every two to three days. Apparently the composition of apple leaves, grown in a greenhouse, differs importantly from outdoor leaves. Though, preliminary comparisons of the activity of different fungicides against apple mildew can be made with success in greenhouse tests.

Summary

Since 1956 studies have been made in the Netherlands on the weather conditions favourable for infection by apple mildew conidia. These observations led to the hypothesis that the most favourable weather conditions for infection by the conidia were at least one day of high relative humidity followed by one or more days of low RH.

The hypothesis has been tested by field experiments in 1958 and 1959. The control achieved by spraying according to this hypothesis was less than by spraying at regular intervals. A probable explanation for this failure is given. The conclusion was reached that mildew infection can take place during periods when the maximum temperature (measured in a meteorological screen) remains considerably below 20° C.

In 1959 and 1960 inoculation experiments on potted M and MM apple rootstocks, reared in a greenhouse, were carried out to verify the data derived from the field observations. Infection occurred over widely varying conditions of temperature and relative humidity.

The level of mildew attack in orchards after spraying every seven days is still rather high. In 1959 two field experiments were conducted to show that complete control of mildew can only be reached by more frequent spraying but spraying so frequently is impractical.

Infection and spraying experiments on greenhouse plants showed a remarkably strong curative action of both dinocap and wettable sulphur. The practical significance of this curative action could not be assessed under outdoor conditions, because the exact date of infection periods are unknown, but the poor results of sprays against apple mildew do not indicate that it is of importance.

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SPRAY TIMING FOR APPLE MILDEW CONTROL

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Summary

Field trials have been carried out at Lenton Experimental Station, to compare the effectiveness of a variety of spray programmes for apple mildew control. The most important period for reducing blossom truss infections is from May until mid-June, when the fruit buds are being formed. Subsequent sprays are of importance for the protection of the vegetative extension shoots and, unless general tip-pruning is resorted to, spraying must be continued until extension growth has ceased and the terminal-bud scales have become suberised.

With a protectant fungicide, sprays should be applied at continuous regular intervals throughout the season to maintain cover of newly emerging foliage. Regular sprays are also necessary when using an eradicant type of fungicide and although intensive early spraying against primary infections reduces the inoculum level in the trees, continued applications are required to prevent a build up of the disease later in the season.

Introduction

Burchill (1958) and Woodward (1927) have shown that P. leucotricha overwinters as resting mycelium in the bud and that the buds are susceptible to infection only until the outer bud scales have become suberised forming a protective cover enclosing the embryonic leaves.

In the mildew-susceptible variety, Cox's Orange Pippin, the fruit buds are formed in May and early June while the vegetative buds are formed progressively throughout the spring and summer until extension growth ceases. Normally the buds are susceptible for the four or five weeks extending from their initiation to the stage at which they become enclosed by suberised scales. Thus the fruit buds and first-formed axillary vegetative buds are susceptible until about mid-June while the later formed axillary and the terminal vegetative buds may remain liable to infection until late August (Burchill, 1958).

Control measures involving the application of fungicides must therefore be aimed at preventing infection of the buds during their period of susceptibility. The buds are normally infected by mycelium growing in from the petiole of a diseased leaf, although some direct infection of the buds by conidia may occur. Hence, in addition to checking the establishment of leaf lesions, sprays should also suppress the production of conidiophores from existing primary infections. The timing of spray applications will therefore depend upon the general mode of action of the fungicide as well as the type and intensity of the infection to be controlled.

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Between 1960 and 1961 two detailed field trials were conducted to establish the relative importance of sprays applied at different stages in the life-cycle of the disease.

Experimental

The 1959-60 trial was carried out on eighteen, four-tree square plots separated from one another by single rows of guard trees. The trial was divided into two blocks to compensate for a slight increase in the incidence of mildew towards the upper part of the field and the nine different treatments were randomised within each block. The experimental trees were Cox's Orange Pippin on M.IX rootstocks, and were 9 years old in 1959, while the guard trees were Cox's Orange, Worcester Pearmain or Janes Grieve of similar age. Sprays were applied by hand lance (high volume) at about 100 lb/sq. in. pressure.

The same general design was used for the 1960-61 trial which comprised two blocks, each of six, four-tree square plots.

The fungicides used were: (1) dinocap, as a commercial wettable powder containing 25% of the active material normally used at 1 lb/100 gallon. Where wetter was required, a 60% solution of sodium di-octyl-sulphosuccinate was added at 8 fl. oz/100 gallon pre-blossom and 6 fl. oz/100 gallon in later sprays; (2) DNC at 0.1% with 2.9% petroleum oil.

Assessments of primary infection were normally carried out in May immediately the blossom truss infections were evident, and repeated some two to three weeks later on the terminal bud infections. About one hundred trusses or extension shoots were counted on each tree and classified as either mildewed or healthy.

Secondary infections were assessed, from June onwards, on extension shoots, selected at random; the leaves were examined for mildew lesions on their under-surfaces. The total number of leaves on the shoot together with the number showing mildew infection were noted in each case. Where a leaf was missing it was counted as mildewed. At least fifty extension shoots were examined in each treatment. The results were expressed as the percentage of infected leaves on the extension shoots of each plot by averaging the separate shoot counts.

1959-60 Trial

The first trial was intended to determine the effectiveness of spray programmes drawn up in accordance with the evidence (Burchill, 1958) obtained in the West of England on the mode of infection of buds. Thus dinocap sprays were applied throughout May and early June to control fruit bud infection and were then continued for varying periods up to the cessation of extension growth. A further programme was arranged in which no sprays were applied during the period thought to be vital for fruit bud protection and a control plot, receiving no sprays at all, was also included.

Two other programmes were included in this trial to compare the effectiveness of dinocap (at 1 lb/100 gallons) and DNC (at 0.1%) in killing out primary mildew infections. These sprays were applied as the buds were breaking with the aim of freeing the young expanding leaves from the disease. The different programmes are shown in Fig. II. In general the sprays are applied at fortnightly intervals and, because of the dry summer, none were adversely affected by rainfall following application. The guard rows were left unsprayed to provide an even source of inoculum throughout the orchard.

Results

An assessment of the primary mildew infection was made on the 21st April, 1959. All the plots proved to be infected to a similar extent (10 - 13%). Even where dinocap or DNC had been applied at bud burst or where dinocap had been applied at green cluster, no significant differences in primary mildew incidence were evident at this assessment.

A series of secondary mildew assessments were made during the summer of 1959. The results of the assessment made on the 24th August are shown in Table 1 and Fig. I. It is evident that the untreated plots (2) showed a high level of infection and that all the spray programmes gave some measure of control.

The results of the sprayed plots may be grouped as follows:
(a) Approximately 70% reduction in infection. Programmes 4, 5, 7 and 8.
(b) Approximately 50% reduction in infection. Programmes 1, 3 and 9.
(c) Approximately 30% reduction in infection. Programme 6.

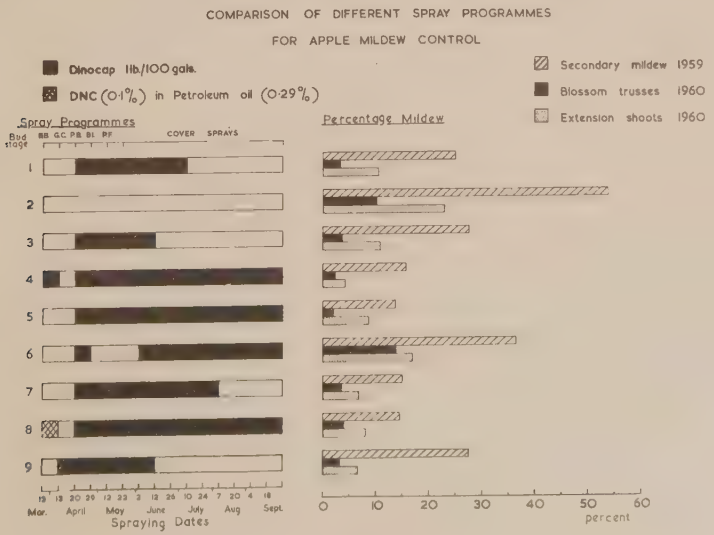

Fig. I

Table 1 Mean percentage mildew infection following different spray programmes

Spray Programme	Secondary Infection Extension Shoot (24.8.59)	Blossom Truss (11.5.60)	Primary Infection Extension Shoot (20.5.60)
1	25.4	3.26	10.54
2	54.0	10.08	23.03
3	27.6	3.72	10.84
4	15.7	2.26	4.23
5	13.8	1.98	8.65
6	36.5	13.85	17.00
7	15.0	3.47	6.84
8	14.5	4.07	8.12
9	27.5	3.13	6.57

In the spring of 1960, the primary mildew infections were assessed. The percentage blossom truss and extension shoot infections are given for each spray programme in Table 1 and Figure I. It is clear that the level of fruit bud infection was unaltered from the preceding season in the untreated plot and in treatment 6. In all other cases the mildew incidence was reduced from 10 - 13% to between 2 and 4%. A later assessment made on the primary extension shoot infections on the 20th May, 1960 reflected the differences already noted at the end of the 1959 season and given by the August assessment of secondary mildew. Although the differences were not so marked at this stage, the untreated plot (2) clearly carried the highest infection and plots receiving programmes 6, 1 and 3 still showed a higher level of infection than the remainder.

Discussion

The even distribution of the disease in the experimental plot is emphasised by the uniformity of the primary mildew counts made in April 1959. The early sprays of dinocap or DNC appeared to have no effect in freeing infected buds from the disease and, in this particular experiment, gave no better control of new infections than a programme omitting these early applications (compare 4 and 8 with 5). Some bud seal was recorded following applications with DNC. The introduction of a spray at green cluster appeared to provide no additional benefit. (compared 9 with 3). Where sprays were omitted during May and early June (programme 6) fruit bud infection was as severe as in the unsprayed plot. (Compare blossom truss assessment for 2 and 6 with remaining programmes).

Finally, the progressive decrease in secondary mildew infections with the application of further sprays from mid-June to mid-August indicates the importance of continuing the protection of the foliage until extension growth has ceased and the terminal bud scales are suberised. Programmes 3 and 9 (concluded in June) and programme 1 (concluded in July) gave inadequate control of secondary mildew. Programme 7 (concluded in August)

gave full control and was in no way inferior to the remaining treatments where sprays were continued until the 18th September. Shoot measurements indicated that, in the dry summer of 1959, extension growth ceased in late July and thus sprays applied in September 1959 would have been superfluous for the control of terminal bud infections.

It will be noted from programme 6, where the mid-season sprays were omitted, that although sprays were applied again from mid-June onwards, very little reduction in secondary mildew was effected. The primary extension shoot infections arising in 1960 in these plots were also much higher than in plots receiving protection during May. It is probable that the inoculum rose to a high level in trees receiving treatment 6 during May and therefore subsequent applications of dinocap were inadequate to regain control.

The evidence obtained in this trial confirms the findings of Burchill (1958). The most important period for mildew control is from the pink bud stage until early to mid-June when the fruit buds will normally be closed by suberised scales. Full protection of the vegetative shoots may only be obtained by continuing to spray until the cessation of extension growth but, in drier parts of the country or where tip pruning is practised, the number of cover sprays may be limited according to economic considerations.

1960-61 Trial

The second trial was carried out to determine the value of an eradicant spray programme for controlling mildew. The main purpose of the experiment was to compare routine protectant programmes with programmes in which the sprays were applied at short intervals, (7 - 9 days), until the end of May to suppress sporulation from primary infections. Thereafter, with inoculum at a minimum, no further sprays were applied.

The trial layout was essentially the same as that used in the previous trial. In this case, however, the guard trees were sprayed with dinocap on every occasion to reduce migration of conidia from the guard rows to the experimental trees; only six different programmes were compared.

All the applications were made with dinocap (1 lb/100 gallons), a material which appears to be primarily eradicant in its action. The six different programmes are shown in Fig. II. It will be seen that programme A consisted of an early series of intensive sprays followed by regular applications until the end of July. Programme D did not begin until the petal fall stage but thereafter followed the same schedule as A. Programmes B and C consisted of intensive eradicant sprays only and were discontinued shortly after petal fall. A and B commenced at the mouse-ear stage while C commenced at pink bud. In programme D, the sprays were applied at green cluster, pink bud, blossom, petal fall and thereafter at fortnightly intervals until the end of July.

Results

The immediate effects of eradicant dinocap sprays were recorded by a series of secondary mildew assessments made between 30th May and 27th July. These results are illustrated in Fig. II where the percentage mildew is plotted on a logarithmic scale. Primary mildew assessments were made in the spring of 1961.

A steady increase in mildew infection was shown in the unsprayed plots (programme O). The initial infection incidence of 0.6% per shoot was very much higher than in any of the remaining plots even though only two sprays had been applied in programme D. None of the treated plots became infected to the same extent as the unsprayed and the relative effectiveness of the different treatments is shown in Fig. II. By the beginning of July the results were as follows:

a) Approximately 90% reduction in infection. Programmes A, D and E.
b) Approximately 70% reduction in infection. Programmes B and C.

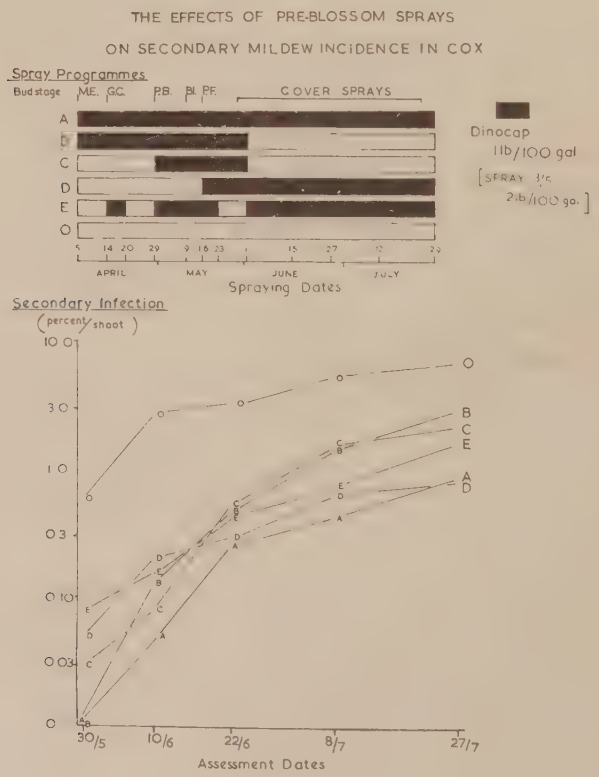

Fig. II

Discussion

Since secondary mildew leaf lesions are caused by germination of mildew conidia alighting on the under surface of the leaf, assessments based on this type of lesion are directly related to the level of inoculum in the tree. The present trial was carried out with a single row of sprayed guard trees and the ingress of inoculum from surrounding plots was sufficiently low not to mask the differences between the various spray programmes. In time, however, the level of inoculum built up in plots receiving no sprays after the 23rd May (when a double strength application was made) and this infection no doubt originated from spores spreading in from other parts of the orchard as well as from diseased shoots which had survived the intensive early spray programme.

It is immediately apparent from Fig. II that a reduction in inoculum was achieved with programmes B and C until the middle of June. However, by the first week in July, the inoculum level was no longer limiting the establishment of fress infections in these plots and, although the incidence of the disease never reached that of the unsprayed plots, control was virtually lost at this stage. A comparison of programmes B and C suggests that the bud burst, mouse-ear and green cluster sprays did not contribute to the reduction in inoculum.

The slopes of the graphs in Fig. II indicate that the build-up rate of mildew in the trees receiving eradicant programmes only was the same as that in the unsprayed plots. The low inoculum level resulting from these early sprays simply caused a delay of about four weeks in the outbreak of secondary infections. The most striking effect is seen by comparing programme A, where sprays were applied continuously from bud burst until July, and programme D, where the first spray was delayed until mid-May. It is evident that the augmentation of a simple protectant schedule (D) by intensive early sprays to suppress sporulation (A) gave no better control of secondary mildew.

In spring 1961, all the treated plots showed at least 70% reduction in the incidence of primary mildew infections compared with the unsprayed controls, but no consistent differences were recorded between the various spray programmes. Blossom truss infections are mainly initiated between the petal fall and fruitlet stages, when the fruit buds are particularly susceptible and it will be seen from Fig. II that all the programmes included sprays which would provide relatively effective control during this period by protection, the suppression of inoculum or both.

This trial has shown that the frequent use of dinocap (or compounds with similar eradicant properties) to suppress sporulation from primary infection does reduce the level of inoculum within the tree. However. once spraying is discontinued the inoculum builds up very rapidly and successive sprays are necessary to maintain a low level. Thus, a series of protectant sprays, applied from late May onwards without a preliminary eradication programme will give a similar degree of secondary mildew control.

General Recommendations

It appears from these results that, whether a fungicide is either predominantly eradicant or predominantly protectant in its action against mildew, sprays should be applied at regular intervals. The intervals should not exceed 10 days for full control (particularly if the material is an eradicant fungicide) and 14 days is the maximum interval for maintaining commercially acceptable control of the disease. Spraying should commence shortly after pink bud and continue at least until early July. Where renewal pruning is practised, it is important to continue mildew sprays beyond this stage until extension growth has ceased.

Acknowledgements

Thanks are due to Mrs. J. Astill and Miss M. Dooley for assistance in spraying and assessing.

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SOME RECENT OBSERVATIONS ON THE CONTROL OF APPLE MILDEW

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Apple Mildew on Bramleys

During the last three or four years growers of Bramley's Seedling have become progressively more concerned about the incidence of powdery mildew on this apple variety. Previously Bramleys were relatively mildew-free especially when compared with Cox's Orange Pippin and it was generally assumed that the variety was, to some degree, resistant. What then is the explanation of the increase over the last few years. The evidence seen by the writer and his colleagues suggests that one of the main factors leading to the increase in powdery mildew on Bramleys is inefficient spraying. In many orchards the mildew incidence is much less at 5 ft. to 7 ft. than it is at the top of the trees, both in terms of primary vegetative tip infection in spring (i.e. tips of extension shoots) and in terms of secondary leaf infection in the middle of the season. In some cases the difference between leaf size and colour at the bottom and top of the tree is easy to see, that at the bottom being full sized green and healthy, while that at the top is in general, twisted and wrinkled with mildew.

Spray deposit tests have confirmed this view. Spray applications of a water soluble dye followed by recovery of the dye show that, in several Bramley orchards where air-blower spraying machines are used, the amount of spray in the tops of the trees is minute as compared to that at the bottom. In some tests the difference is five-fold, while in some it is considerably more (20 - 30 x). The inference is that the air blower spraying technique has allowed a progressive build-up of mildew over the years, and the centre and top of the tree has been the seat of this build-up.

There are two steps therefore which should be taken in developing control measures for this newly important mildew of Bramleys: firstly, the method of spraying these trees should be improved to provide a considerable increase in the deposit in the tops and centres of the trees; secondly, a spray programme is required to combat the infection.

During the autumn of 1960 and the season 1961 tests have been made with dinocap in order to determine the most effective dates of application in a programme specially suited to Bramley.

1960 Trial

Examination, in July 1960, of trees severely infected with mildew showed that the mildew was predominantly in the tips of the 1959 extension growth. There was very little primary mildew infection of rosette leaves (that is to say of buds formed early in 1959) and this aspect of the mildew infection appeared to be of relatively minor importance (unlike mildew on Cox).

In view of this infection pattern it was argued that spraying in July and August, to prevent axillary and tip bud infection, might be of special practical value in the control of mildew on Bramleys. If infection was mainly late in the season (later than is the case with Cox) such a programme might be sufficient to reduce the mildew level and in time be sufficient for commercial control.

Accordingly 10 Bramley trees were chosen at random in an orchard for spraying, and a similar group of 10 chosen as untreated controls. Three applications of dinocap at 1 lb of the 25% WP per 100 gallons (plus a wetter), were made by hand lance, the trees being well drenched to ensure, as near as possible, perfect cover. The dates of application were August 8th, August 22nd, September 5th.

In the following spring the trees were examined from time to time until the most suitable time to conduct a count of infection had arrived. This was 21st June. Early examination, it was considered, would not have been suitable as much of the primary infection on vegetative tissue was not readily seen until June was well advanced.

The most convenient way to assess the incidence of primary infection on vegetative (extension) shoots was to count the total number of such shoots both infected and not infected present on each tree below a height of approximately 8 ft. This limitation was imposed in view of the relative inefficiency of the previous spraying. A count, within the same part of the tree, was also made of primary infection of spurs (rosettes) (i.e. buds formed and matured early in the previous season). Results, given in full for each replicate, are set out in Table 1.

As will be seen from these figures, no good whatever was obtained from this late season spraying either against vegetative tip infection or against spur bud infection. The latter could not reasonably be expected but the total failure against the former is somewhat surprising and tends to show that early protection is necessary.

Table 1 Assessments of primary infection

TREATED Applied: Aug. 8, 22 Sept. 5					UNTREATED				
Tree	Infected spurs per tree	Number of tips		% infected tips per tree	Tree	Infected spurs per tree	Number of tips		% infected tips per tree
		Clean	Infected				Clean	Infected	
1	10	137	23	14.3	1	11	136	12	8.1
2	10	116	11	8.7	2	13	116	14	10.8
3	6	89	13	12.8	3	12	139	9	6.1
4	12	103	5	4.6	4	9	105	14	11.8
5	10	128	16	11.0	5	10	128	7	5.2
6	18	117	8	6.4	6	36	117	10	8.6
7	17	141	15	9.6	7	6	91	4	4.2
8	10	105	11	9.5	8	12	113	19	14.4
9	14	125	6	4.6	9	12	146	15	9.3
10	14	110	7	6.0	10	4	63	10	13.6
Total & Mean % age	121	1,171	115	8.94		125	1,154	114	8.99

1961 Trials

Before the above results were available, it was decided to conduct trials designed expressly to determine whether short programmes (of limited number of sprays as compared with Cox programmes), starting relatively late in some cases, would be sufficient for mildew control on Bramleys. In Bramleys, unlike Cox, there is seldom much evidence of true fruit bud infection. Occasional primary fruit bud infection with obvious infected flowers can be seen but this form of the disease is not a serious problem as it is with Cox. There is however a degree of spur-bud infection (i.e. of rosette leaves, normally emerging early in the season) as seen from Table 1. These spurs produce leaves and, depending on the degree of infection, either continue to produce infected leaves for some time or lose all their leaves early on and die. In general these spur infections are not easily seen, their density per tree is not great, and they do not seem to be of great economic importance in themselves. Certainly they are insignificant in producing an impression of mildew later in the season as compared with the extension shoot infections. It was against this background that the seasons spraying trials were arranged.

Later in the season sections for microscope examination were made from a number of these spur infections to see whether they were in fact fruit buds turned blind by infection. Only one out of 10 such buds showed any sign of flower initials; they are vegetative buds unless the infection is so early that it arrests the "flower initial" development - (this would be greatly different from the situation with Cox).

The trials arranged were of two types: (a) commercial, treatment being made in commercial orchards using standard spraying machinery; (b) small scale with replicated single tree plots. In both cases the material used was dinocap at 1 lb 25% WP per 100 gallons or 4 lb per acre.

a) Commercial Trials

Five trials were conducted in which 2 or 3 experimental programmes each of 2 sprays of dinocap were superimposed on a standard scab/mildew programme.

Assessments of primary infection were made in the first fortnight in June by counting 2 x 100 shoot tips (1960 extension growth) on each of 10 trees giving a total of 2000 tips examined per treatment. Assessments of secondary infection were made in late June - July: 10 shoots (1961 extension growth) were examined per tree, on each of 10 trees, 10 leaves per shoot, making a total of 1000 leaves examined per treatment. All counts restricted to the lower half of the trees.

Results, expressed as % tips infected - Primary (P) and % leaves infected - Secondary (S) - are given in Table II.

Table 2 Assessments of primary (P) and secondary (S) infection

Site	All programmes 2 applications of Dinocap								
	1. Pink Bud 2. + 7 days		1. Petal Fall 2. + 7 days		1. Petal Fall + 14 days 2. + 7 days		Standard Programme		
	P	S	P	S	P	S	P	S	
1	24.8	39.3	27.9	45.8	31.2	55.6	37.9	62.7	PMN throughout
2	32.8	54.6	34.4	71.8	42.7	58.3	-	-	-
3	23.2	38.8	24.7	56.7	31.9	59.7	35.7	74.9	Lime sulphur preblossom Mercury post-blossom
4	30.9	37.4	36.9	53.4	37.8	52.0	41.3	58.1	Mercury throughout
5	-	-	24.1	18.2	27.8	33.9	27.5	31.2	Lime sulphur throughout
6	5.0	50.1	9.7	48.9	7.8	52.5	7.9	23.7	Dinocap 5 applications

b) Small Scale Replicate Trial

One trial only was conducted, with nine young Bramley trees per treatment. The spray programme compared included two in which dinocap was applied throughout the season and three in which the programme was of two sprays only with one interval of 7 days.

(i) Dinocap 1 lb 25% WP/100 gallons every 14 days from April 13 (Pink Bud) to July 19.
(ii) Dinocap ½ lb 25% WP/100 galllons every 7 days from April 13 to July 19.
(iii) Dinocap 1 lb 25% WP/100 gallons at Pink Bud. Repeat at 7 days.
(iv) Dinocap 1 lb 25% WP/100 gallons at Petal Fall. Repeat at 7 days
(v) Dinocap 1 lb 25% WP/100 gallons at Petal Fall + 14 days. Repeat at 7 days.
(vi) No mildew treatment.

Assessments were of primary infection made in first half of June by counting 2 x 50 tips on each within a treatment making 900 tips examined per treatment. Assessments of secondary infection were made 13th June: 10 new shoots (1961 extension growth) were examined per tree on each of the nine trees, 10 leaves per shoot making 900 leaves examined per treatment. Results are given in Table 3.

Table 3

Treatment Dinocap (25% WP)	Primary Mildew % infected shoots	Secondary Mildew % infected leaves
i 1 lb Full prog. (14 days)	39.4	28.5
ii ½ lb Full prog. (7 days)	35.1	13.6
iii Pink Bud + 7 - 1 lb	44.5	46.1
iv Petal Fall + 7 - 1 lb	38.1	34.8
v (Petal Fall + 14) + 7 - 1 lb	46.4	41.3
vi No treatment	54.8	71.1

A full programme commencing at Pink Bud gave the best control of mildew on Bramley - just as it does with Cox. Also, as with Cox, the 7 days half rate programme is better than a 14 day programme at the full rate.

Of the shortened programmes none approaches the full treatment in efficiency but there is an indication that the sprays applied at Petal Fall and 7 days later are the most efficient. There is also a reduction in apparent primary infection with all treatments. This is an interesting side effect and may be ascribed to the eradication of the infection emerging with the bud. On the other hand it is not always easy to distinguish between an early secondary and a primary infection. Dinocap treatment may have reduced the number of early secondary infections which tends to confuse the operator.

The trials reported tend to show that a good commercial control of mildew on Bramleys cannot be expected from two applications of dinocap when infection is high. A full programme (preferably four or five applications) would be needed in such conditions. There is evidence that relatively early treatment is required for Bramley just as for Cox, and in 1961 the optimum period for satisfactory response to sprays was at Petal Fall and 7 days later.

Apple Mildew on Cox's Orange Pippin

Apple mildew of Cox differs, as mentioned, from that of Bramley in that primary infection of fruit buds is commonly seen. This infection generally destroys the florets, and all parts fall off, leaving a malformed stump, which for a short time is capable of acting as a source of infection. For this reason growers commonly go to much trouble to cut out the infected buds.

For some time now there has been an indication that dinocap applied at the Green and Pink Bud stages at double the normal rate (2 lb 25% WP per 100 gallons) can take the place of this 'cutting out'. The exact manner in which this is done is not fully understood but it is probably through a combination of eradication of the surface sporulation on the shoot, and an enhanced protection of the new tissue.

Small scale trials using single tree plots are not suitable for demonstrating the effect of dinocap in this way owing to cross infection. Only on large areas can the benefit of such a treatment be felt.

In 1961 such a trial was carried out by a grower in Kent. A section of the orchard was sprayed at the Green and Pink Bud stages with dinocap at 2 lb of the 25% WP per 100 gallon rate (double the normal rate). A comparable section was not so sprayed but instead the infected buds were cut out in the traditional way. Both plots received the usual dinocap programme as well as these treatments.

Later in the season casual inspection showed that the plot receiving sprays and no 'cutting out' was the worse of the two, but careful counts of both primary and secondary infections were done to determine the true position.

Ten trees in each plot were chosen for examination. All primary infections whether of fruit buds or of vegetative tip buds were counted and recorded per tree. For the assessment of secondary infection, ten shoots were chosen at random per tree and on each shoot the top 10 leaves were examined for infection, making 1000 leaves examined per plot. Most shoots had 10 leaves only so the sample taken included the first-formed leaves of the 1961 extension growth.

On the trees receiving double-rate dinocap sprays, the number of primary infections per ten trees were 548, on unsprayed trees with 'cutting out' it was 381. The percentage leaves with secondary infection on both treatments was 48.2. 'Cutting out' has therefore reduced primary infection but the number of such infections (38.1 per tree) is remarkably

high. Despite the difference in primary infection, secondary infection was similar in sprayed and 'cut out' trees, an indication that the spray application has equalled the 'cutting out' technique in reducing infection sources.

These results are related to those of the 1960 Report of the Luddington Experimental Horticulture Station (p. 4), where cutting out was found to have very little influence on subsequent secondary mildew in the same season. It may be in the trial now reported that neither cutting out nor early double strength spraying had any effect upon the secondary mildew, this being the reason for the lack of difference between them. Either of them may, however, have affected the fruit bud infection which occurs relatively early in the season. Counts at the Pink Bud stage in 1962 will determine this.

THE CONTROL OF SECONDARY INFECTION OF APPLE MILDEW BY DINOCAP AND THE COMPARISON OF VARIOUS METHODS TO ASSESS FORMULATION EFFICIENCY

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Introduction

At the Horticultural Research Station at Ongar we have, since 1958, been seeking methods for assessing the efficiency of certain fungicides and spray programmes in the expectation that any degree of disease control could be related to a change in the general condition and health of a tree. Therefore, our assessment methods were directed towards measuring the appearance, yield, and fruit quality of a tree as well as the actual amount of mildew associated with a treatment. We considered that recording the general appearance of trees was particularly important as this is the factor by which a grower can most easily judge the effect of a programme for mildew control.

Primary mildew in spring and the later summer secondary infection can both be used to measure the level of apple mildew infection. Secondary mildew on leaves was chosen as the most suitable factor because - (1) it is the stage of the disease on which a chemical spray has a direct and immediate effect, (2) it is the stage which has the most direct and obvious effect on the appearance of the tree, and (3) its distribution is fairly uniform and it can be used to indicate disease progress.

This paper describes the method of assessing secondary infection of mildew on leaves and examples of results of field experiments show how these measurements of secondary infection can be related to the number of leaves lost by mildew attack, the appearance of the tree and the russetting of fruit at harvest. In addition, the measure of infection of leaves over whole shoots by the method described by Baker (1961) was used. There are also examples of how this method is associated with the secondary mildew assessments and appearance scores.

Our work started with investigating the activity of a number of compounds, including ethylene 1,2-di(N'N'-dimethylthiuram disulphide). This compound has, as yet, no British common name, but it will be referred to throughout this report as tecoram, which is the common name used in Holland, its country of origin. Work has also been carried out with dinocap to investigate the effect of volume of application and the addition of certain scab fungicides on final mildew control. Several assessment methods have been used in each case to demonstrate the differences in activity of various mixtures and formulations.

Experimental

All field experiments on apple mildew were carried out in orchards of the variety Cox's Orange Pippin either at the Ongar Research Station or on the farms of growers in Kent and Essex. Usually two or three-tree plots were used with three or four such plots randomised for each compound or programme tested. On these plots spraying was carried out at high volume, 200 gallons per acre, with a modified Craven Machine and hand lances. In the 1961 experiments, designed to compare the activity of dinocap at high and low volume rates of application, the low volume treatments were applied with an experimental machine delivering 30 gallons of spray per acre and the high volume plots received 200 gallons per acre, applied automatically.

The assessments of secondary leaf mildew were made by systematically sampling leaves on specific trees on each plot. These trees were selected at the beginning of the season and used throughout for assessment purposes. Every third leaf was picked from extension shoots over 1" long, every third extension shoot was selected and every third lateral of each branch examined. This method produced about 100 leaves per tree, at each sampling. Leaves in each sample were counted in the laboratory and then graded according to the extent of mildew on their surface. Grades used were as follows:

Clean	-	no mildew
Trace	-	1 - 25% of surface mildewed
Moderate	-	26% - 50% mildewed
Severe	-	over 50%

Leaf assessments were made twice or thrice in a season and used to show the build-up of disease and persistence of effect of various control programmes.

On one site in 1959 a leaf assessment method was used to measure the proportion of leaves lost by severe mildew infection. Trees from which leaves were taken for sampling of mildew could not be used for this, as some leaves would have been removed for previous assessments. In this case, duplicate trees were used which were reserved on each plot for this purpose. The extension shoots were selected in the same way as for the leaf mildew assessments and a count was made of the number of leaf scars and leaves present on each extension shoot.

By mid-August some plots were easily recognised as looking in better condition than others. It was believed that this could be attributed to some plots losing more leaves than others by mildew attack or to the general poorer quality of foliage where mildew control had been less efficient. In these cases individual plots were scored for general appearance by two or more observers according to the following scheme.

General description of tree or plot	Score	Score range
Very poor	x	0.6 - 1.5
Poor	xx	1.6 - 2.5
Moderate	xxx	2.6 - 3.5
Good	xxxx	3.6 - 4.5
Very good	xxxxx	4.6 - 5.0

Fruits were picked from all plots at harvest and graded out for russetting on an absolute scale, disregarding the natural russet commonly associated with Cox's Orange Pippin.

In 1961 the method developed by the N.A.A.S. (Baker, 1961) was used to assess secondary mildew infection over complete shoots. 20 shoots are examined per plot and graded arbitrarily as to whether there are 1%, 10%, 50%, 75% or 100% mildewed leaves.

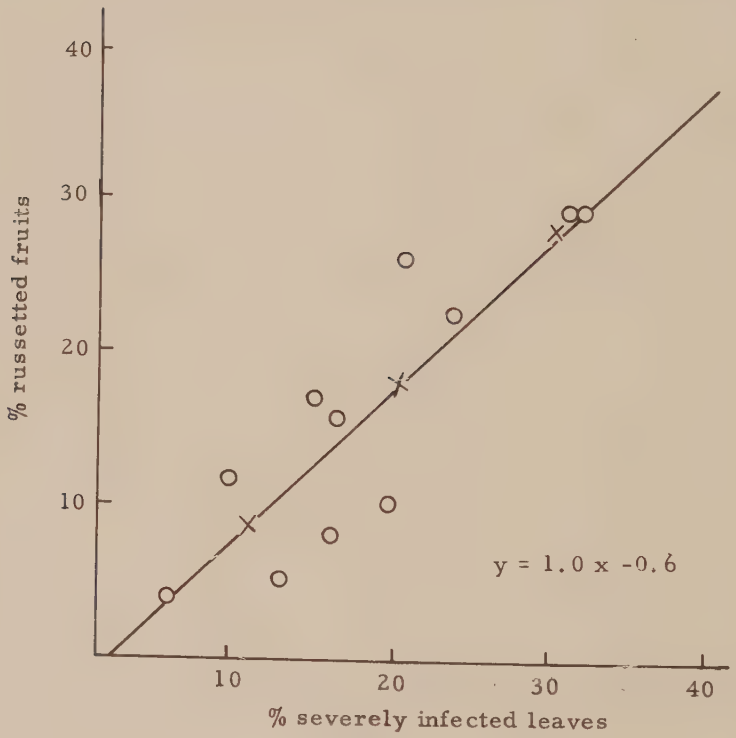
Results

The extent and progress of mildew attack

Table 1 shows the use of the leaf mildew assessment method to distinguish between 3 programmes for mildew control. Three tree plots were used and there were three replicate plots for each programme. Assessments were carried out on each tree of each plot. In this case the leaf gradings for the three assessments were analysed together. The ziram plus dinocap programme gave the significantly highest number of clean and lowest number of severely infected leaves. In this experiment there were also large differences in fruit russetting between some treatments. The figures for the percentage of severely russetted fruits have been plotted against the relative figures for severely mildewed leaves and a significant correlation has been obtained, as shown in Fig. 1.

Fig. 1 1958 Experiments. Site 1. Ongar, Essex.

Correlation between severely russetted fruits and severely mildewed leaves



Correlation highly significant at P = 0.01

Table 1 1958 Experiment

Site 1. Ongar, Essex

Control of apple mildew by tecoram and ziram programmes and related fruit russetting

Variety - Cox's Orange Pippin

Application rate of formulated material lb/100 gal. (4 applications)	Concen. Active compound %	Mean no. of leaves per category per tree from 3 assessments. (% per category in brackets)				% severely russetted fruit at harvest
		Mildew				
		Clean	Trace	Mod.	Severe	
tecoram $2\frac{1}{2}$ lb	0.2	25.0* (32)	15 (19)	25 (26)	13* (16)	18
ziram 1 lb + sulphur 2 lb	0.08 0.14	30** (34)	16 (19)	28 (34)	11* (13)	10
ziram 1 lb + dinocap 1 lb	0.08 0.025	32** (41)	17** (23)	20 (26)	8** (10)	7
Control (unsprayed)	-	18 (26)	11 (15)	23 (32)	19 (26)	22

Coefficient of variation = 69%
L.S.D. between treatment means (numbers of leaves = 6.0 when P = 0.05
8.0 when P = 0.01

Spray applications:- 7th May, 3rd June, 16th June, 30th June.
Formulation - tecam = wettable powder containing 80% ethylene 1,2-di(N'N'-dimethylthiuram disulphide)
ziram = wettable powder containing 80% active compound
dinocap = " " " 25% " "
sulphur = " " " 70% " "

The same leaf assessment method was used the following year to compare a series of programmes containing tecoram, dispersible sulphur, dinocap and captan. In this case spraying was carried out at 80 gal. acre and 12 or 24 tree plots were used, with 3 replicate plots for each programme. 2 trees were marked in each plot at the beginning of the season and used throughout for sampling purposes. The results of the work are expressed in Table 2 as the percentage of severely infected leaves at each count for each treatment. The dinocap containing programmes maintained the best control, while applications were being maintained but there were smaller differences between treatment by mid-August. The figures for the % severely russetted fruit again fell into line with % mildew and a significant correlation was obtained (Fig. 2).

Table 2 1959 Experiment

Site 3. Pearsons Green, Kent.

Control of apple mildew as measured by % of leaves with secondary infection and % russetted fruit at harvest

Variety: Cox's Orange Pippin

Treatment date & application rate of formulated material (lb) in 80 gal. acre				% severely infected leaves		% severely infected leaves		% severely infected leaves	% severely russetted fruit
Spray 3/4	Spray 16/4	Spray 27/4	Spray 4/5.26/5 9/6	1st count	Spray 18/6.6/7 20/7	2nd count 20/7	Spray 29/7	3rd count 19/8	Harvest
tec 4	tec 4	tec 4 sul 4	tec 3 sul 4	19**	tec 3	38**	As for 20/7	49**	52
tec 4	tec 3 sul 3	tec 3 sul 3	tec 3 sul 3	15**	tec 3	35**		58	22
tec 4	tec 4 dino. $1\frac{1}{2}$	tec 4 dino $1\frac{1}{2}$	tec 3 dino $1\frac{1}{2}$	13**	tec 3	32**		50*	20
cap 4	cap 4	cap 4 sul 4	cap 3 sul 4	28**	cap 3	43**		56*	44
Control	-	-	-	51	-	56		74	54

Analysis. L.S.D. for first count when P = 0.05 is 14, 0.01 " 18 c. of v. = 43%

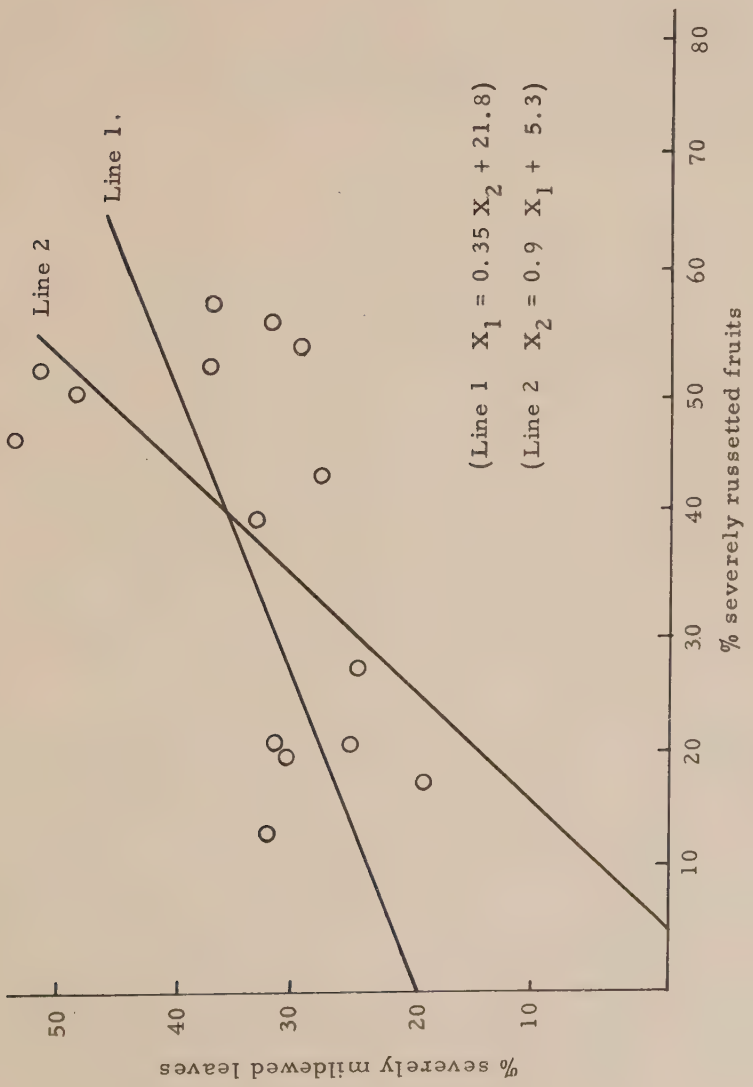
L.S.D. " second " " P = 0.05 " 9, 0.01 " 12 c. of v. = 26%

L.S.D. " third " " P = 0.05 " 17, 0.01 " 23 c. of v. = 30%

Formulations. tec = tecoram as w. powder containing 80 % ethylene 1,2-di(N'N'-dimethylthiuram disulphide)
sul = sulphur as a 70% wettable powder
cap = captan as a 50% wettable powder
dino = dinocap as a 25% wettable powder

Fig. 2 1959 Experiments. Site 3.

Correlation between severely russetted fruits and severely mildewed leaves



During the course of the 1958 and 1959 experiments, it became apparent that the assessment of secondary mildew by sampling was costly in both time and labour. Although differences between programmes could be detected it was necessary to take very large samples in order to overcome assessor and 'between tree' variations. It had been observed that by July and August untreated trees could easily be picked out from treated trees by reason of their poor foliage. In an experiment to compare two wettable powder formulations of dinocap, a count was made of the number of leaves missing by mildew attack and the trees were also scored for their general appearance. Dinocap was applied at rates of 0.25, 0.5 and 1.0 lb active material per 100 gal. in two wettable powder formulations, A & C. Results of this work are shown in Table 3.

Table 3 1960 Experiments

Site 3. Pearsons Green, Kent.

Comparison of two wettable powder formulations of dinocap, with or without tecoram for mildew control

Rate of 25% compound in lb/100 gal.	2.0		1.0		0.5		Control	Coeff. of Variation	Least Sig. Dif.
Formulation	A	C	A	C	A	C			
% mildewed leaves 14/7	11	21	22	22	33	31	50	42	14
16/8	17	17	22	21	24	27	52	28	8
Missing leaves 12/8	1.4	4.8	3.5	2.9	5.2	4.5	9.0	47	2.7
Appearance score									
with tecoram	3.7	4.4	3.8	4.2	3.7	3.8	1.8		
Rating	Good	Good	Good	Good	Good	Good	Poor	14	1.5
without tecoram	3.9	3.6	3.9	3.8	3.7	3.6	1.5		
Rating	Good	Good	Good	Good	Good	Good	V. Poor		

It was thought that the assessment of mildew on whole shoots as described by Baker (1961) would be simpler to operate than our own leaf sampling method. Appearance scores, leaf sampling and shoot assessments were all used this year to compare formulations of dinocap.

In the first experiment (Table 4) a 25% wettable powder formulation (No. 5) was compared with four 50% emulsifiable concentrate concentrate formulations, (Nos. 1-4). All were applied at a rate of 0.5 lb active dinocap in 30 gallons water per acre at each of 5 applications. Tecoram at 4 lb of the 80% formulation per acre was applied with each formulation and on its own (No. 6). Treatment No. 7 was unsprayed control. 6 dwarf pyramid trees were used for each plot and there were three replicate plots per treatment, with a guard row of trees between each plot. The ranges of activity as assessed by each method are summarised in Table 6 below.

Table 4. 1961 Experiment. Ongar.

Comparison of methods for assessing control of apple mildew by formulations of dinocap and tecoram applied at low volume

Treatment: grouped in order of activity / Method		5	1	2	3	4	6	7	Coeff. of Variation
Leaf mildew assessment 28.6.61.	% infected leaves	16.0	20.9	24.2	21.9	24.2	39.6	48.6	37
N.A.A.S. shoot assessment 16.8.61.	Total for 20 shoots	57.3	71.0	65.3	65.3	104.3	23.4	427	41
	% infection per shoot	2.9	3.5	3.3	3.3	5.2	11.7	21.3	
Appearance score 31.8.61.	Total for 9 shoots	30.2	30.0	27.5	27.0	27.0	21.7	19.7	5
	Mean per tree	3.4	3.3	3.1	3.0	3.0	2.4	2.2	
	Rating	Mod.	Mod.	Mod.	Mod.	Mod.	Poor	Poor	

Duncan's Range Test (Duncan 1955) was used to test significance; for any one assessment method any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different.

Treatments:
1. dinocap as 50% emulsifiable concentrate X
2. dinocap as 50% emulsifiable concentrate X
3. dinocap as 50% emulsifiable concentrate X

(wetter content at three different rates) — dinocap at rate of ½ lb per acre + tecoram (80% formulation) at 4 lb/acre.

4. dinocap as 50% emulsifiable concentrate Y. Single concentration of wetter.
5. dinocap as 25% wettable powder A
6. tecoram (80% formulation) 4 lb/acre only
7. Unsprayed control.

Spray application dates. 26th April, 9th May, 19th May, 2nd June, 19th June.

Table 5 1961 Experiments. Ongar

Formulations of dinocap

Treatments ranged in order of activity

Assessment Method	1st	2nd	3rd	4th	5th
Leaf mildew	5	1 3	4 2	6	7
N.A.A.S.	5	2 3	1 4 3	6	7
Appearance	5	1 2	4	6	7

In the second experiment, six different formulations of dinocap as wettable powders were compared. All were applied to give the same rate of active material, i.e. 0.5 lb/acre. Each formulation was applied at high and low volume and with or without an additional scab fungicide. Two-tree plots of 10-year-old trees were used in a split-split-plot layout with three fold replication.

Table 6 summarises the result by all methods of assessment, and Table 7 is a breakdown of the 'appearance score' method, showing relative appearance of the formulations with each of the scab fungicides.

Table 6 1961 Experiments. Boreham, Essex

Control of apple mildew with different wettable powder formulations of dinocap

Dinocap applied at 0.5 lb active compound per acre on all treatments

Formulations		A		B		C			Coeff. of Variation	Least Sig. Dif.
Treatment No.		2	3	4	5	6	1	7		
Wetter rate		x1	x2	x1	x2	x1	0	Control		
Leaf mildew (Mean of all plots) 2 counts	% severely infected leaves	41.1	40.5	45.1	44.5	45.8	46.3	62.4	22	6.8
'NAAS' shoot assessment 17.8.61. (Mean of all plots)	Total for 20 shoots	522.8	590.3	617.8	606.9	534.7	545.1	1161.7	29	225.4
	Mean % mildew per shoot	26.1	29.5	30.8	30.3	26.7	27.2	58.1		
Appearance score (Mean of all plots) 23.8.61.	Per plot	3.2	3.2	3.2	3.1	3.2	2.9	1.4	18	0.35
	Rating	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.	V. Poor	-	-
% missing leaves		21.7	29.2	27.4	27.1	30.1	27.5	33.8	N.S	-
Sub. %		3.8	4.4	5.4	4.9	7.1	4.7	6.2	N.S	-

Spray applications on 15th April, 2nd May, 15th May, 27th May, 8th June.

Table 7 1961 Experiment. Boreham, Essex

Effect of adding scab fungicides to activity of formulation of dinocap

Mean appearance scores for High and Low volume plots together

Formulation	A		B		C		
Treatment No.	2	3	4	5	6	1	Control
Wetter rate	x1	x2	x1	x2	x1	x0	
+ tecoram	6.3 M	7.0 M	6.0 M	6.0 M	6.5 M	5.3 M	3.2 P
+ captan	6.8 M	5.8 M	6.2 M	6.2 M	6.7 M	6.2 M	2.8 VP
No scab fungicide	6.0 M	6.2 M	6.5 M	6.5 M	6.0 M	5.8 M	2.2 VP

LSD between any two scab fungicides with the same dinocap formulation = 0.98 when P = 0.05

Discussion

Fruit russetting

The correlations obtained between severely infected leaves and russetted fruit is interesting, but does not necessarily mean that the russet is due directly to mildew growing on the fruit. There are reports especially in the U.S.A., that this is possible, but no attempt was made to isolate the fungus from the fruits. Russetting is more likely to have been caused by exposure of fruits to the wind, cold or excessive heat. The fruit on the trees where foliage was reduced by mildew attack would be more exposed and consequently become more russetted. It is possible that, under the conditions of the experiment shown in Table 2, the high degree of russetting with the first treatment is associated with the higher level of sulphur in this programme.

Advantages and limitations of the assessment methods

The leaf sampling has its limitations, mainly because of the large 'between tree' and 'between plot' differences that a comparatively small sample of 100 leaves will produce. Variations will also arise through 'between block' differences when one assessor samples and grades one

block. In the experiments in which the method has been used the coefficients of variation range from 26 to 69%, but generally between 40 and 50%. Variation could probably be reduced by having one assessor to pick samples and grade leaves for all blocks. This would take too long, especially when two or three sites are considered, and the best way is to use three or four assessors, sampling and grading from one site at a time.

The N.A.A.S. 'leaves on shoots' method has the advantage that one assessor can grade a whole site in about the same time that he could pick leaves for the sampling method on one block only. There is the added advantage that once he has examined a tree or plot he has a reading for that unit and does not have to carry out a second operation of examining leaves individually. From the two experiments in which the method has been used it appears that the coefficient of variation is of the same order as with the leaf sampling method. This is probably because of size of sample examined, 100 to 150 leaves in one, and 20 shoots in the other, represents approximately the same proportion of foliage in the tree.

The low variations associated with the appearance scoring are mainly due to the fact that whole plots and not samples are being assessed. Relatively small differences between treatments can be detected, and this is the only method which has enabled some distinction to be made between the effects of adding scab fungicides to dinocap formulations (Tables 3 & 7).

Activity of formulations of dinocap

In the straight comparison of wettable powders (Table 3), the 2 lb rate of formulation A leads to the lowest percentage of mildewed leaves and the loss of significantly fewer leaves than the other treatments. There is a tendency for formulation A to be slightly better than C at both the 2.0 lb and 1 lb levels. By comparing the appearance scores of the 'with tecoram' and 'without tecoram' plots separately it can be seen that there is a tendency for formulation C to be more active at any given rate with tecoram, whereas when no scab fungicide is added, A is the more active.

In the comparison between wettable powder and emulsifiable concentrate formulations (Table 5), treatment No. 5, the wettable powder, is obviously the most active on all counts. A distinction between the emulsifiable concentrates (treatments 1 - 4) is difficult but by scoring each treatment in order of its rating by each method (Table 6) treatments 1, 2 and 3 are grouped together, with treatment 4 as the least active of the group. This is particularly interesting as the basic formulation for treatments 1, 2 and 3 is the same, the only difference being the quantity of emulsifier incorporated. Treatment 4 is an emulsifiable concentrate of a basically different formulation. Tecoram alone (No. 6) has provided a significant control of mildew although it is not as active as dinocap.

In the work on the wettable powder formulation of dinocap all the basic treatments were applied at high and low volume and with or without the two scab fungicides, tecoram and captan. An analysis of variance of the treatment means of the percentage of mildew leaves showed that there was no significant difference between high and low volume applications, nor

between the means of scab fungicide plots. The results in Table 6 are therefore expressed as the mean of 18 replicates. By whatever method they are assessed the differences in activity between the dinocap wettable powder formulations are extremely small. Treatment 2 is rated first by four and second by one of the 5 methods. The remaining treatments containing wetter fall into no fixed order of activity, but No. 1, without wetter, is the least active. It could therefore be said that the addition of wetter to a powder formulation of dinocap enhances its activity and that the quantity and type of wetter in treatment 2 is optimum for the control of mildew under these conditions. This treatment also gives best scab control. In the analysis of variance of the appearance score there was a significant interaction between scab fungicide treatments and dinocap formulation. Table 7 shows that for a given dinocap formulation there are significant differences between the scores for the scab fungicide used. For instance treatment 3 appears to be more active when used with tecoram than with captan and there is a significant influence on the appearance of the tree when tecoram is used on the control (no dinocap) treatments. Further work is in progress to see if there is any correlation between these differences and the deposit of dinocap on the leaf surface.

Acknowledgements

I should like to acknowledge the encouragement and advice given to me by Mr. K. Carpenter. My thanks are also due to Mrs. B. Bryant and Mrs. J. Fagg for their help with the statistical analyses, to Miss E. M. Noyes and members of her unit for help with leaf sampling and to the members of the Field Experiments Department under Mr. C. W. Wilson for their part in the actual spraying and assessment work.

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THE EFFECT OF APPLE MILDEW ON YIELD AND THE RESULTS OF SPRAYING TRIALS FOR ITS CONTROL

by J. Ingram
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The significance of apple mildew infection is well recognised but little information is available of the actual effect it has on tree growth and cropping. The first trial carried out was designed to show the effects of allowing the disease to develop and also to compare the control given by spray programmes of dinocap and phenyl mercury nitrate. Phenyl mercury nitrate was included because of observational evidence that it gave some mildew control.

Trial 1

The trial began in 1957 on five year old trees of the variety Lane's Prince Albert worked on M VII rootstock and planted at 15 feet square.

Treatments

Key	Material	Formulation and amount per 100 gal of spray
DN	dinocap at 0.025% + wetter at 0.015%	1 lb 25% wettable powder 4 fl.oz 60% dioctyl sodium sulphosuccinate
PMN	phenyl mercury nitrate at 0.00316%	2 lb of a wettable powder containing 1.58% organically combined mercury.
O	Unsprayed for mildew	

The sprays were applied by hand lance at high volume rate. Four applications were made in 1957 between 3 April and 11 June, five applications in 1958 between 22 April and 19 June and seven applications in 1959 between 31 March and 13 July. To provide uniform control of scab all trees received a captan programme applied separately from the treatments and full control measures were taken against pests. No cutting out of mildew infection was carried out beyond that achieved by the routine light regulated pruning.

Results

Records were taken of the proportion of blossom trusses showing infection at the pink bud stage and of leaves with infection in June/July. Table 1 gives details.

Table 1 Mildew infection

	% of blossom trusses infected			% of leaves infected	
	1958	1959	1960	1958	1959
DN	0.3	0.3	0.1	15.1	9.7
PMN	1.4	4.1	3.7	45.0	46.1
O	1.6	4.9	8.5	59.3	68.4
Sig. diff. at 0.05 level comparing 1 with 2	0.71	1.85	1.85	8.17	4.57
" 1 or 2 with 3	0.80	2.07	2.00	9.14	5.11

Dinocap kept the incidence of mildew down to low levels throughout the trial. The mercury programme gave only slight control of leaf infection and significant effect on blossom truss infection was shown only in 1960.

Table 2 Extension growth per tree

	1958			1959		
	Number of shoots	Shoot length cm	Total growth cm	Number of shoots	Shoot length cm	Total growth cm
DN	159.5	37.1	6205	198.3	29.7	5805
PMN	126.5	28.8	3870	157.9	28.6	4591
O	101.5	25.3	2670	108.8	23.8	2669
Sig. diff. at 0.05 level comparing 1 with 2	50.20	6.55	2274.5	80.98	4.40	2503.7
" 1 or 2 with 3	56.10	7.32	2543.0	90.54	4.92	2799.2

Where mildew infection was not controlled the trees made less than half the total extension growth of those where mildew was effectively controlled with dinocap. The increased growth under dinocap was associated with increases in both shoot length and number. The trees receiving mercury made growth that was intermediate between the dinocap and unsprayed trees but the increase over those unsprayed did not reach significance.

Table 3 Yields bushels (40 lb) per acre

	1957	1958	1959	1960	1957-60	Fruitlet drop as a % of total crop 1959
DN	44	152	280	506	983	39.1
PMN	22	132	77	298	529	75.9
O	44	160	110	256	571	38.5
Sig. diff. at 0.05 level comparing 1 with 2			54.1	90.6	108.8	8.33
" 1 or 2 with 3			60.5	101.2	122.9	9.31

In 1957 and 1958 the yields of the dinocap sprayed trees did not differ from those of the unsprayed trees but the increases in growth being made by the sprayed trees during this time were followed by a highly significant increase in yields from the dinocap trees in 1959 and 1960. The 1960 yields measure residual effect; the treatments were not applied in that year. Fruitlet drop was associated with the mercury programme and this depressed yields in each year. With no mercury application in 1960 the trees previously sprayed with mercury showed their first crop increase over the trees unsprayed for mildew.

Trial 2

In this trial commencing in 1960 a full dinocap programme of eight applications was compared with the first four only, the last four only, and with trees unsprayed for mildew. In addition each plot was split; on one half mildew infection was cut out at the pink bud stage and on the other half no cutting out was done. The dinocap was applied as before at 0.025% + wetter at 0.015%. Spraying began at the mouse ear stage and the first four applications were completed by petal fall. The second four began 12 days after petal fall. The same trees were used as for trial 1 the new treatments being re-randomized over the existing plot layout.

Results

Table 4 Mildew infection

	% of blossom trusses infected	% of leaves infected		
	1961	1960	1961	
			R	NR
1. Full dinocap	0.74	32.0	11.0	11.9
2. Early dinocap	4.4	74.3	72.3	73.5
3. Late dinocap	2.9	54.2	33.9	34.9
4. Unsprayed for mildew	10.1	85.7	87.8	91.4
Sig. diff. at 0.05 level				
1 v 4 or 2 v 3	2.59	6.44		
1 or 4 v 2 or 3	2.65	6.59		

R = mildew infection cut out at the pink bud stage. NR = not cut out

The full eight applications gave the best results. The four late sprays gave a better control than the four early sprays. The results suggest that the early sprays were applied too early and the late sprays too late. Although the early sprays are shown to be of less value they do appear to influence the incidence of mildewed blossom trusses in the same year. This was best shown in the first year 1960, when the treatments were imposed on similar existing infection. A record of mildewed blossom trusses was taken on 3 May and where two applications of dinocap had been made (on 1 and 20 April) the level of infection was 2.6% mildewed trusses compared with 4.4% where no early applications were made (Sig. diff. at 0.05 level = 1.54). Little advantage from this early control of blossom truss infection, however, is shown in the level of subsequent leaf infection. Similarly the cutting out of infection at the pink bud stage has not at this stage of the trial, reduced the amount of subsequent leaf or blossom truss infection.

Other trials on the station have shown a neat lime sulphur programme on Cox to be equally as effective against mildew infection as a high volume programme. Both methods of application however increased the incidence of fruit drop. Applications of DNC petroleum on Cox in early March have also significantly reduced the number of mildewed blossom trusses but had little effect on subsequent leaf infection.

Summary

A spray programme of up to seven applications of dinocap with added wetter gave an effective control of powdery mildew infection on the variety Lane's Prince Albert. The trees made more than double the extension growth of those unsprayed for mildew and yields showed a similar increase by the third year. Four late applications of dinocap beginning after petal fall were more effective than four early applications applied between mouse ear and petal fall, but the results suggest that the late applications began too late for good control. Application of dinocap before pink bud reduced the amount of blossom truss infection in the same year but had little effect on subsequent leaf infection. Cutting out of mildew infection at the pink bud stage did not reduce the amount of subsequent leaf or blossom truss infection.

Phenyl mercury nitrate on Lane's Prince Albert gave only moderate mildew control and caused fruit drop which depressed yields.

High volume and concentrate application of lime sulphur on Cox were equally effective in controlling mildew, but both increased fruit drop. DNC-petroleum applied to Cox in early March reduced the number of blossom trusses showing infection but had little effect on later leaf infection.

Details of Discussion

Q. Mr. C. D. Lindley

What level of blossom truss infection affects the yield of apples, and below what level should treatment control infection to prevent loss of yield?

A. Dr. R. T. Burchill

I haven't actually done trials or examinations in this respect. The only observation I can make is that in the Long Ashton trial the percentage of infection on the control trees was about 6% which was nevertheless fairly high. A value below 6% would I feel represent a good control.

Mr. J. Ingram commented:

8 - 9% can harm the crop.

Dr. J. E. Crosse asked:

Several of the speakers have mentioned the importance of reducing primary infections in the orchard by pruning and spraying etc., but none of the experimental evidence indicates that this has any permanent effect on the development of secondary infections during the summer. In how many instances in these experiments has secondary infection originated from the unsprayed control trees? Is it possible in the conventional type of field experiment to demonstrate any relationship between primary and secondary infections?

Dr. R. O. Sharples stated:

I agree that a certain amount of the secondary infection which develops in experimental plots undoubtedly comes in from the unsprayed control plots and from the neighbouring orchards. Unless a completely isolated orchard is available, the prevention of this source of infection presents a very difficult experimental problem. It also involves a great deal of extra labour since the guard rows must be sprayed very frequently. In our trial we randomised all the treated plots except the unsprayed controls, (Programme 2), which were deliberately placed on the corners of the orchard where the prevailing winds would tend to carry mildew spores away from the treated plots. This compromise was justified since we were mainly interested in the effects of the different spray programmes, and the untreated plots were merely included as a guide to the general level of infection in the orchard. When looking at the trees, after applying frequent eradicant sprays, it was apparent that a few primary infections did escape complete eradication. This led me to suggest in my paper that much of the subsequent secondary infection arose from inoculum produced within the treated plots themselves but I believe that we also got some infection coming in from neighbouring orchards. Infection from this latter source may have limited the effectiveness of the eradicant programmes and had we been working in an isolated orchard, the subsequent build-up of mildew in plots which were sprayed up to the end of May only, might have been less. Nevertheless there was still a marked reduction in the inoculum level within these plots during June.

Mrs. Baker

I would like to refer to the trial we did in Suffolk, reported in my second paper, where we had four plots, quite sizeable ones, and within each of these four plots we had four trees only which were thoroughly pruned in spring to get rid of primary infections. In addition, four were left unpruned and the whole of the rest of the trees were commercially spring pruned. It is interesting to note that we found certain differences between the four trees which had had very thorough spring pruning, and the commercially pruned trees, and the unpruned ones. We found differences in the percentage of spur buds distorted in the Autumn, and differences in the amount of shoot infection, and I think there is an important distinction here. Leaf infections seem to occur on a large scale, tending to minimise tree to tree differences, in a 'blanket' infection, whereas spur bud infection (occurring early in the season) and perhaps shoot infection too, seem of a more limited nature, in a more particular type of infection. There this may well be spread from unsprayed control to sprayed trees in trials as far as leaf infections are concerned although clear differences may show up during or immediately after the spray programme is complete. This is why it is of value to do more than one set of records in a trial, on different tree parts, and also why it is so important to discover if possible the conditions of infection in the field, not only for leaves, but for buds and growing points of shoots. Perhaps infection conditions are different for leaf surfaces and for the compacted tissues of buds and growing points, because in our Suffolk trial and in other observations we got effects on spur buds which were not apparent in leaf counts, following spring pruning.

Mr. D. Hunnam commented:

Dr. Crosse's question can be expressed in another way. Sometimes small replicated single tree plots are used to obtain information. Sometimes large single plots of many trees are used: these two methods will give a different assessment of the importance of cross infection.

We have done both ourselves. We have found in small scale plots there is an indication that high rates of Karathane prevented sporulation of the mildew and that this was reflected in the primary mildew in the subsequent year. Bearing in mind that there was cross infection in the same season it is not possible in small plot trials like these to determine the true effect of such treatments upon the secondary mildew. In large plot trials cross infection is reduced, and you find reference to such a trial in my paper, but I didn't get round to it. Pink Bud and Green Bud applications have not had any reflection whatsoever in secondary infections later in the season. In the same way extensive cutting out of mildewed trusses at the pink bud has had no effect upon secondary mildew.

This is not to say both treatments will not affect the primary fruit truss infection.

Dr. R. O. Sharples commented:

We also found that sprays applied at pink bud or earlier did not reduce the incidence of secondary infections later in the season.

Mr. R. W. Marsh asked:

Would you like to comment on the suggestion that the effect of mildew as shown on fruit is an indirect effect?

Ir. G. S. Roosje answered:

In the paper you will see this difference between Mr. Terry's opinion and what I said in my paper. I feel that the russeting is largely due to direct mildew infection. This is supported by our 1960 experiment, where only one spray less resulted in much more mildew russeting on the fruits and one can hardly imagine that a difference of only one spray would have so much influence on the condition of the foliage. I believe we come closer to each other when one bears in mind that my experiments were carried out on Jonathan, whereas the experiment of Mr. Terry was carried out on Cox. Mildew russeting is much more severe on Jonathan fruits than on Cox fruits. With respect to Golden Delicious and Cox, I agree largely with Mr. Terry's findings.

Mr. H. J. Terry responded:

I don't think we disagree at all. All I said was that we hadn't actually shown the direct effect on mildew growing on the fruit surface but that obviously there is a relationship between the russet and the amount of mildew on the tree. In my tables, I think that is probably clearer in Tables 1 and 2 of my paper. The earlier programmes, and the more effective ones certainly are associated with the lower percentage of russeting.

Dr. R. T. Burchill remarked:

I have seen apple mildew growing on Comice pear's but not on Cox's Orange Pippin apples. Frequently it is claimed that mycelial infection of fruitlets (the mycelium later disappearing as the apples mature) is responsible for much of the russeting seen on Cox fruit at harvest. Although this has never been satisfactorily proved it would seem that if this russeting was caused by mycelium then examination of sections from affected areas of the fruit may show the presence of encapsulated haustoria in the cells, thereby providing evidence of a previous mildew infection.

Ir. G. S. Roosje stated:

I found on a few fruits a little mildew mycelium in a very early stage of the fruits. I agree with Dr. Burchill, that usually one starts to look too late for actually finding mildew mycelium on the fruits. The occurrence of mildew mycelium on apple fruits is for instance known from the United States (Washington State) and is also well known in Switzerland, where this fact has been established by Dr. Zobrist and cooperators (see Dr. Zobrist's commentary on the subject).

Dr. R. O. Sharples commented:

Two years ago, at Lenton Experimental Station, we inoculated the flowers of Jonathan trees by dusting them with mildew conidia. The trees were grown in pots in a greenhouse. We obtained infection of all the floral parts and the mycelium grew vigorously on the surface of the sepals. Although, in a few cases, the mycelium later spread to the surface of the fruitlet, just below the sepals, the severity of the infection of the style prevented the fruit from setting. We therefore did not show the growth of mycelium on the fruit itself but it did appear that the fungus will grow on the flowers and young fruitlets of Jonathan. Mycelium was also recorded on the sepals and petals of Cox and Worcester Pearmain flowers following inoculation with mildew conidia in the greenhouse.

Q. Mr. G. D. Angell

The suggestion that the increase in mildew infection in Bramleys is, I take it, where growers are using a specific mildew fungicide. Is it not more attributable to climatic conditions and the turn over from lime sulphur to mercury on an erradicant programme? Few Bramleys growers are at present using a specific mildew fungicide, and although many growers may be turning over to low volume spraying, high volume spraying still finds more favour with many growers of Bramleys and yet the increase in mildew would seem as high with these growers as low volume users.

A. Mr. D. Hunnam

The answer here is that the mildew increase is, I think, directly attributable in part to the simple fact that there is not enough of the fungicide in the right place. Where lime sulphur is being used there is just not enough penetrating up to the tops of big trees. This fact, I should imagine, applies to most of the air application machines which are available and I don't intend to refer to any single make of machine. How important it is I don't know for certain. I imagine it is very important but as we are in the relatively early stages we have got to be careful. I am quite sure that this is something of sufficient importance to be looked into.

Dr. R. T. Burchill answered:

In this country the only approach of this nature has been with D. N. O. C. / petroleum sprays. Dr. M. H. Moore has shown that an application of this spray just before bud-burst resulted in a reduction in the number of primary infections that subsequently emerged.

Recent experiments with December applications seem to suggest that spraying at this time may give an even greater reduction in the amount of overwintering mildew.

Dr. Zorbrist's commentary on his slides:

Apple Mildew (Podosphaera leucotricha) as a cause of russetting apples

Known causes of russetting of apples have been till now: (1) frost damage during or shortly after blossom; (2) cold and adverse weather conditions during the development of the fruit; (3) phytotoxicity from chemicals, such as sulphur and copper.

The russetting resulting from one or several of these causes usually covers a smaller or larger uninterrupted area of the fruit surface. Damages from adverse weather conditions may also lead to cracks, grooves or deformation of the fruit, besides russetting.

With the increased incidence of apple mildew fine, web-like russetting has appeared on the fruit, quite distinct from the russetting from the above mentioned causes. The finish of the fruit is considerably impaired. Growers usually attribute this to "spray injury".

In our experimental orchards we found this type of damage in the years 1958/59/60 in untreated plots as well as in plots without mildew treatments.

Variety	Russetting caused by P. leucotricha % of 22,000 apples examined from 1958 - 1960		
	Untreated check	Treated against scab and insects but not against mildew	Treated against scab, insects and mildew (*)
Golden Delicious	45	37	1
Jonathan	42	37	4
Cox	58	45	5
Gravenstein	15	16	3

(*) 2x wettable sulphur and 3x dinocap beginning at pink-bud.

From these results it follows that there is a connection between the control of P. leucotricha and occurrence of web-like russetting on the fruit. That the mildew is in fact the cause of this russetting was confirmed in a field test at our Coppet experimental station. At the end of May, 1960, 1,611 apples in untreated plots showing microscopic mildew infections were labelled. At this stage the infection shows up as a white fungus layer mainly in the calyx zone. Mildew infections on the fruit only occur during the blossom and fruitlet stages.

P. leucotricha sporulates normally on the youngest apples. It does not, however, spread on the epidermis of the growing fruit. The fungus is probably unable to perforate the epidermis at a later stage.

The 1,611 labelled apples were examined two months later at the beginning of August and it was found: (1), that the mildew infections were confined to the initially attacked area of the fruit surface; (2), that the mycelium was not as easily recognisable as at the time of labelling, except on Golden Delicious; (3), with the growing fruit the epidermis expanded and the infected zones were distinctly russeted, and (4), that of the labelled fruit 20 - 35% had been shed during the physiological June drop.

Variety	% labelled apples from untreated plots examined after harvest, showing		
	visible mildew infections	mycelium with positive plasmolysis reactions	web-like russetting
Golden Delicious	58	25	78
Cox	41	10	97
Jonathan	55	22	81
Gravenstein	63	-	72

The microscopic examination confirmed that the visible mycelium was P. leucotricha. No perithecia were found on the fruit.

In conclusion I would say that our investigations at Dielsdorf and Coppet have shown that: infections by P. leucotricha occur during the blossom or fruitlet stage of the apples; P. leucotricha can live on apples infected during blossom until harvest; the fungus actively penetrates the epidermis of the fruit with its mycelium and haustoria; the perforation of the epidermis by the fungus causes typical web-like russetting of the growing fruit; specific sprays for mildew control during and after blossom prevent the web-like russetting of the fruit.

SESSION V

PESTS OF TREE FRUITS: CONTROL OF RED SPIDER MITE, CODLING MOTH AND TORTRICIDS

Chairman: F. R. Tubbs, East Malling Research Station

ASPECTS OF BIOLOGY OF IMPORTANCE IN TIMING SPRAYS AGAINST FRUIT TREE RED SPIDER MITE, CODLING MOTH, AND THE FRUIT TREE TORTRIX MOTHS

by G. H. L. Dicker
East Malling Research Station

FRUIT TREE RED SPIDER MITE, Metatetranychus ulmi

Since few chemicals are highly toxic to the winter eggs, and the performance of these is so intimately related to the efficiency of application, it is almost universal practice to direct control measures against the early summer generations. Recent biological studies have therefore centred on the hatching period and development of the early generations, in an attempt to find a relationship with the blossom period, the last well defined stage of bud development which can be easily recognised and used as a guide to timing sprays.

Hatching period of the winter eggs

From data obtained during the Essex investigations (Blair and Groves, 1952) and subsequently from general orchard observation it had been concluded that hatching began just before the blossom period, about half the eggs had hatched by petal fall, and the remainder hatched over a further period of 3 - 4 weeks.

Whilst this may be representative of most orchards, recent studies have shown that considerable differences in the hatching period can occur. For example, the dates of 50% hatch in two orchards at East Malling (Fig. 1, A and B) where the overall period followed the anticipated course, differed by 9 and 17 days respectively in 1960 and 1961. In a nearby commercial orchard (Fig. 1, C) hatching had only just begun at 10 days after petal fall in 1961, and all stages of the hatching period occurred four weeks later than in the earlier orchard (A) at East Malling.

Although a lack of consistency has thus been shown to exist between orchards in any one season the available data suggests a greater measure of consistency for the same orchard in different seasons. In the East Malling orchard (A), where hatching conformed most closely to the expected pattern, the following stages were reached:-

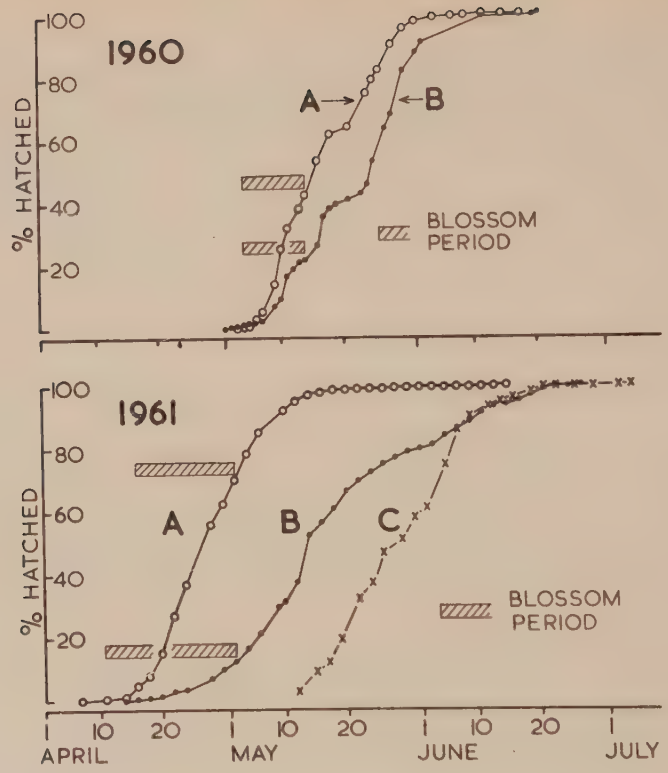

Fig. 1. The hatching period of winter eggs of M.ulmi, at East Malling (A and B) and in a nearby commercial orchard (C).

	1960	1961
Date of, and % hatch at, petal fall	May 14th (42%)	May 2nd (70%)
99% hatch	June 4th	May 18th
100% hatch	June 15th	June 13th

Thus 99% hatch occurred 21 and 16 days respectively after petal fall.

Development of the early generations

Before the hatch of winter eggs is complete the earliest mites have matured and begun to lay summer eggs. The development of this generation has been followed only in orchard A (Fig. 2). Both in 1960 and 1961 the first summer eggs were seen 10 days after petal fall when the hatch of winter eggs had reached 75% and 95% respectively. Production of summer eggs increased rapidly, exceeding the number of mites within two weeks. These eggs began hatching on 9th June 1960 and 3rd June 1961, 16 and 22 days after the first were laid. From this stage onwards the numbers of eggs and mites fluctuate but seldom do the latter exceed more than half of the total population. The period of minimum egg population has occurred about 10 days after petal fall in each year.

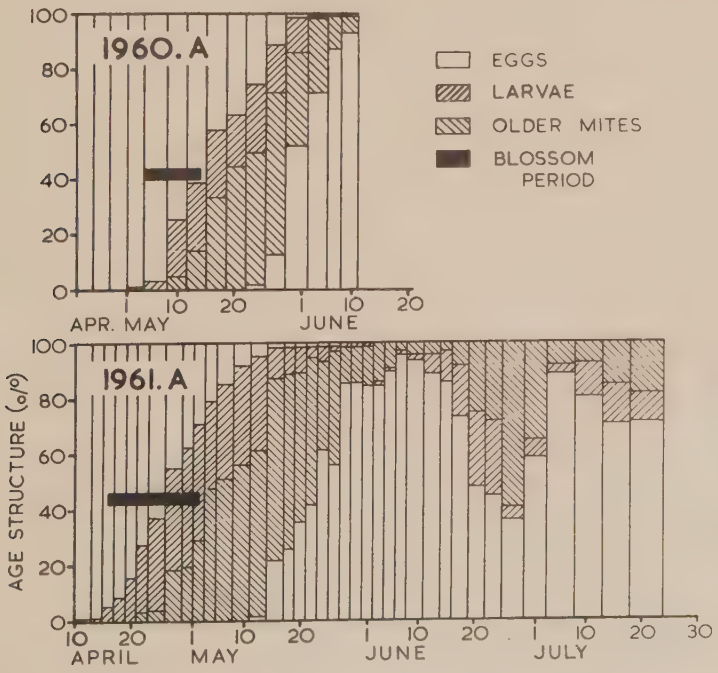

Fig. 2. The relative proportions of eggs, larvae and older mites of M. ulmi during the early generations; orchard A, East Malling.

Duration of various stages in the first generation

From data available, which refer only to laboratory studies, it is clear that temperature is the most important factor controlling the duration of each stage. For example, under constant conditions, the incubation period of summer eggs varies from 23 days at 56° F. to 9 days at 70° F. This emphasises the difficulty in quoting figures for stages exposed to fluctuating temperatures in the orchard. The following times have been estimated from the appearance of the first specimens in recent field studies and probably overestimate the average duration of each stage:-

	1959	1960	1961
Duration of immature stages	20	13	29 days
Preoviposition period of female		about 3 days	
Incubation period of eggs	26	16	22 days

The main point concerning these data is that, if summer eggs are present, a chemical toxic only to active mites will permit survival unless its effective residual period exceeds the incubation period of the eggs, and the surviving mites may in turn be laying more eggs after about two weeks.

Timing of spray applications

Field experience during the past decade has indicated that, in general, two sprays are necessary each year if good control is to be maintained throughout the summer. The actual times at which these are applied will depend on: (1), the population of overwintering eggs; (2), the stages against which the chemical is toxic; (3), the period of residual toxicity.

Where winter egg populations are high the first spray should be applied as near petal fall as possible to avoid foliage injury whilst fruit is setting. With low egg populations and no risk of immediate foliage injury control measures could be directed against the second generation.

CODLING MOTH, *Cydia pomonella*.

Because young larvae tunnel into fruits immediately after hatching it is essential to kill them before any injury has occurred. For this purpose a detailed knowledge of the oviposition period is required but has not been attained because of the difficulty of finding adequate numbers of eggs. As an alternative, studies have centred on the adult which can be caught in light and bait traps, the former being more efficient. But data obtained from such sources are not entirely satisfactory as they reflect adult activity rather than oviposition. For example, the threshold temperature for flight is about 50° F. and that for oviposition a few degrees higher, but the optimum conditions for egg-laying are above 60° F. Furthermore, the light trap only becomes effective when natural light intensity drops to a very low level; it does not therefore give any information on activity during the evening period.

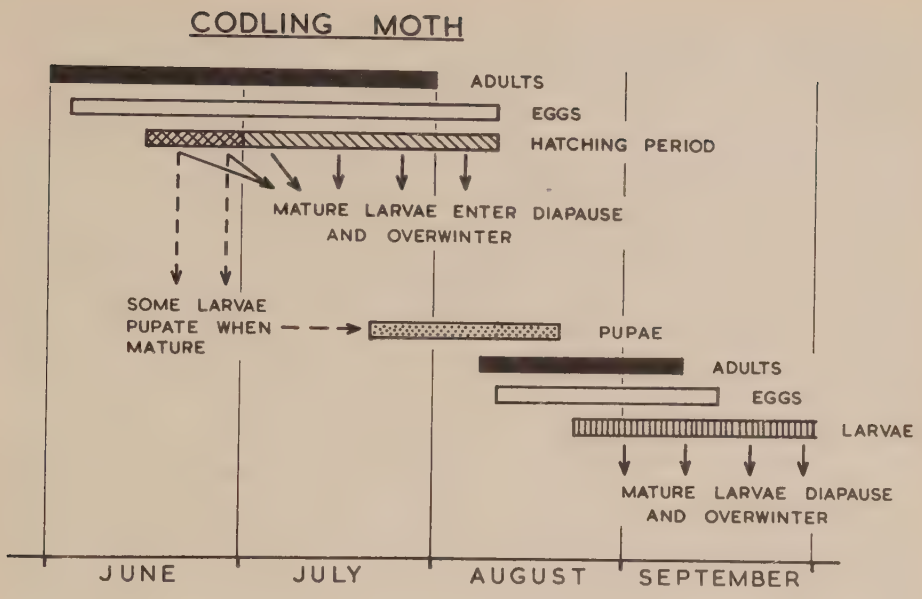

Fig. 3. Diagrammatic representation of life cycle of C. pomonella in south-east England.

A mercury vapour light trap has been in use for the past ten years at East Malling and, whilst the date of the earliest catch has varied from mid-May to mid-June, the composite picture presented by the full records shows that, on average, flight is first noted at the beginning of June (Fig. 3) and moths are present in the orchard until September. These are composed of adults emerging from the overwintered larvae, which occur until early August, and a partial second generation which flies during the rest of the period. Peak flight usually takes place in late June or early July, coinciding with a period of relatively high evening temperatures.

If allowance is made for a preoviposition period of two days, an incubation period of 12 days (varying from 8 days at 70° F. to 15 days at 60° F.) it will be noted that, under average conditions in south-east England, eggs laid by the earliest moths would not normally start hatching until mid-June.

Of the larvae hatching between mid-June and early July a proportion, which is less than half this total, will pupate when fully fed and give rise to the partial second generation. The rest of these larvae and all that hatch later will enter diapause when mature and overwinter in cocoons on the trees or stakes.

In recent years emphasis has been placed on the control of the earliest hatching larvae as a means of eliminating the partial second generation and thus reducing the overall flight period. Assuming this to be possible, it then becomes necessary to apply sprays which will give protection from mid-June to the end of July. The number of, and time interval between, applications will depend on the period of effective residual toxicity of the chosen chemical. With the most persistent ones an application in mid-June followed by another three weeks later has given excellent control.

There is, at present, no wholly satisfactory method of predicting when the first eggs will be laid. A heat summation formula gives a fairly accurate guide to the emergence of the first moth but has to be considered in relation to prevailing evening temperatures when assessing the possibility of oviposition. Often the earliest captures consist of single moths, separated by intervals of several days, and under conditions of such low density mating may not take place. Until more information on these aspects is available it seems probable that mid-June will become the recognised time for the first spray against codling moth and this will be varied only when trapping records and prevailing climate conditions depart from normal.

THE TORTRIX MOTHS

Of the many species which occur on apples only three are of economic importance, and these can be recognised by the type of injury caused to the fruit.

The fruit tree tortrix, Archips podana, is most widespread and damage, in the form of irregular shallow feeding areas, occurs to mature fruits in September and early October. Injury by the summer fruit tortrix, Adoxophyes orana, is similar but a much larger area of the surface is damaged by the maturing larvae of the first summer generation in July and August. Larvae of the fruitlet mining tortrix, Pammene rhediella, occur in June and make a few discrete feeding holes, about a millimetre in diameter, varying from shallow punctures to tunnels which penetrate deeply into the flesh.

The fruit tree tortrix moth

Overwintered larvae emerge from their cocoons at about the bud burst stage and burrow into the fruit buds where they remain in a protected position until green cluster. The remainder of the larval life, until late May or June, is spent in webbed leaves. Light trap captures of the adult show two discrete flight periods, corresponding to the first and partial second generations, from mid-June to mid-August and again in September and early October. Thus the flight period parallels that of the codling moth but occurs about two weeks later.

There are two periods when control is possible - against the overwintered larvae before the blossom period and against the first summer generation in June and July. Since larvae burrow deeply into the fruit buds between bud burst and green cluster the obvious time to spray is at either

the beginning or the end of this period, but experimental data on the relative merits of bud burst and green cluster applications are at present lacking. Whilst a routine preblossom spray may give adequate control on some farms there is also evidence that, on others, this will not prevent injury to the mature fruit. Recent work has therefore concentrated on the control of the first summer generation and, since this follows very closely that of the codling moth, a common spray programme against both species seems possible.

The only results available are for 1960 trials. In these a high degree of control was obtained with azinphos-methyl and 1-naphthyl N-methylcarbamate when applied in mid-June and early July; a further spray in late July did not contribute towards control. If these results are confirmed it would appear that the normal times of application for codling moth should also be suitable for A. podana.

The summer fruit tortrix moth

The life cycle bears a close resemblance to that of A. podana, the main differences being a slightly earlier flight period of first generation moths, which starts in early June, and another complete generation of adults in August and September. Since damage is caused by the maturing larvae arising from the first flight of moths it would be expected that the previous recommendations should also be applicable to this species. The only experimental evidence available is a trial with DDT, toxaphene and parathion (Groves and Tew, 1953) when a marked reduction in damage followed applications on 5th and 23rd June, dates which were subsequently considered by the authors to be too early to give optimum results.

The fruitlet mining tortrix

Information on the life cycle in England rests on evidence gleaned from general orchard observations and the known details are in close agreement with those reported by Vogel, Klingler, and Wildbolz (1956) for Switzerland. Moths are present during the blossom period and probably for a short while afterwards. Eggs, closely resembling those of the codling moth, are laid mainly on the undersides of the rosette leaves and the larvae, on hatching, migrate to the young fruits. Where a fruit cluster is present the larva lives in the centre, protected by copious webbing; single fruits may be entered at the calyx or have a leaf attached to the side. By early July the larvae are mature and spin a cocoon under bark which forms the resting place until a new generation of moths emerges in the following year. This species has only one generation a year.

Once the larvae have reached the fruit and produced some webbing control is probably made difficult by the protection afforded by the webbing. The most susceptible period is at petal fall or shortly afterwards; in Switzerland satisfactory control has been obtained during the ten-day period immediately following petal fall and, in England, similar results have been obtained with DDT.

no cases of resistance have so far been recorded here, some of the conventional materials do not always give a satisfactory control. This could be due to wrong timing or insufficient coverage from changes in spraying technique. Extensive trials with azinphos-methyl against codling moth have shown it to be as good as, and often better than, conventional materials. In a replicated field trial carried out in Norfolk during 1960, a 20% DDT emulsion sprayed on 14th June, 1st and 23rd July at 8 pints/50 gal./acre yielded 3.4% by weight of attacked fruits, whereas the azinphos-methyl 20% emulsion sprayed on the same dates at 3 pints/50 gal./acre gave only 0.9% of attacked fruits.

Although three sprays may be necessary in some seasons where a second generation occurs, two sprays will usually be sufficient, applied at the normal timing, i.e. mid- to end June, and early mid-July. For instance in a trial carried out in 1960 and recorded in the East Malling Research Station for 1960 (p.31), three applications of azinphos-methyl and DDT in mid-June, early and late July gave a 95% control of codling damage. Omission of the last spray had a negligible effect; omission of the June spray, however, reduced the efficiency of the materials by about 25%. Timing, particularly of the first spray, is of great importance and it is usually this spray which causes the greatest reduction in codling moth damage. In fact, a single spray of azinphos-methyl at a rate of three pints per acre in one trial gave a reduction of 75% in the number of attacked apples compared with the unsprayed plot; DDT gave a reduction of 50%.

Emergence of the moths obviously varies from year to year, and the normally accepted spray timings, i.e. 3rd week June and mid-July, whilst giving a perfectly adequate control in many seasons, will, in a few seasons, fail. There are indications that timing is not quite so critical when azinphos-methyl is used. For instance, in a fully replicated trial carried out in 1958 at Rowhill Experimental Farm, where spraying was carried out rather late owing to unsuitable weather conditions, azinphos-methyl reduced the percentage of damaged fruits by 88.6%, whereas DDT reduced it by only 54%. This greater latitude in the use of azinphos-methyl is probably due to its ability to kill codling larvae up to three days after they have entered the fruits, and to its pronounced ovicidal effect.

Codling moth is even more of a problem in other parts of the world where ten or more sprays may have to be applied at 10 to 14 day intervals throughout the season. Azinphos-methyl has proved very effective under these rather more rigorous conditions. The results of a trial carried out in Italy using both formulations are shown in Table 1. Nine sprays at high volume were applied at intervals of 10 to 14 days. Sampling was carried out on the total yield.

Table 1 Results of a trial carried out in Italy against codling moth

Material	Percentage (product)	Percentage attacked apples
Azinphos-methyl 20% Emulsion	0.1%	3.4%
Azinphos-methyl 20% Emulsion	0.2%	1.3%
Azinphos-methyl 25% Wettable Powder	0.1%	5.9%
Azinphos-methyl 25% Wettable Powder	0.2%	3.3%
Control		86.0%

Resistance to lead arsenate and DDT is widespread in many parts of the world and here again azinphos-methyl has proved very effective (See Table 2). This trial was replicated twelve times, using single tree plots and sprays were applied six times at 10 to 14-day intervals. Assessment was made at harvest time on the total yield.

Table 2 Results of a trial carried out in South Africa against DDT resistant codling moth

Material	Percentage (product)	Percentage attacked apples
Azinphos-methyl 25% Wettable Powder	0.1%	10.6%
Azinphos-methyl 25% Wettable Powder	0.2%	3.1%
DDT 50% Wettable Powder	0.2%	28.6%
Control		40.6%

Similar results have been obtained from Australia and the United States.

SUMMER TORTRIX MOTHS

These moths are becoming an increasing problem in some fruit growing areas. Although the damage they cause is largely superficial, it results in downgrading of the fruit and provides an entry for fruit rotting fungi. The two most important species are the surface eating tortrix (Cacoccia oporana) and the summer fruit tortrix (Adoxophyes orana). The former is more widespread and also more difficult to control, since the

no cases of resistance have so far been recorded here, some of the conventional materials do not always give a satisfactory control. This could be due to wrong timing or insufficient coverage from changes in spraying technique. Extensive trials with azinphos-methyl against codling moth have shown it to be as good as, and often better than, conventional materials. In a replicated field trial carried out in Norfolk during 1960, a 20% DDT emulsion sprayed on 14th June, 1st and 23rd July at 8 pints/50 gal./acre yielded 3.4% by weight of attacked fruits, whereas the azinphos-methyl 20% emulsion sprayed on the same dates at 3 pints/50 gal./acre gave only 0.9% of attacked fruits.

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caterpillars are well-protected by their habit of spinning two leaves together, or a leaf to a fruit. Azinphos-methyl has given outstanding results against this pest with two sprays applied as for codling moth. In a 4x replicated trial in 1958 at the Rowhill Experimental Farm, azinphos-methyl 20% emulsion, sprayed on 30th June and 24th July at 0.1 per cent and about 200 gal/acre, reduced the percentage of damaged fruit from 13.0 on the control trees to 0.1 per cent, whereas a 26/27 per cent DDT emulsion sprayed at 0.3 per cent at the same rate and on the same dates gave 1.1 per cent damaged fruits. In another trial carried out in 1960 different spray timings were used, anda lso gave excellent results (see Table 3).

Table 3 Replicated trial against surface eating tortrix

Spraying dates: 16th June and 3rd August
Volume: Low volume, 25 gallons per acre

Material	Damaged apples out of 100 September 19th				
	1	2	3	4	Total
Azinphos-methyl 20% Emulsion at 3 pints/acre	0	0	0	0	0
Control	9	0	9	3	21

Two sprays would appear to give a perfectly adequate control in most seasons. In the East Malling trial previously referred to, three sprays applied mid-June, early and late July gave a 97% control of damage (69% for DDT). Two early sprays applied to a different site gave a 92% control. In both cases the application rate was 100 gallons per acre. Although lower volumes have given good results, they are not generally recommended as good coverage is essential against this pest.

The summer fruit tortrix (Adoxophyes orana) occurs locally in some places in Kent and, although figures are not available from trials conducted in this country, azinphos-methyl has given good results in Holland where this pest is widespread. A single spray applied during the third week of June reduced the number of damaged leaves by about 95% compared with the unsprayed control; DDT gave a reduction of 82%. Besides being effective against the larvae of tortrix moths, azinphos-methyl is ovicidal to both species.

FRUIT TREE RED SPIDER MITE (Metatetranychus ulmi)

The fruit tree red spider mite is becoming an increasingly important pest, particularly where lead arsenate for codling moth has been replaced by insecticides which are damaging to predators and yet do not control red spider mite. Azinphos-methyl, on the other hand, is a good acaricide as well as being effective against codling moth, and though not harmless to predators, is less damaging than some of the currently used insecticides. In the early trials with azinphos-methyl it was used specifically against red spider mite and its performance tested alongside a number of other acaricides. In a fully replicated trial carried out at Rowhill Experimental Farm in 1959, when infestations were generally severe, three sprays applied on 29th May, 22nd June and 20th July, using 0.2% formulated product, kept the population at a very low level and seven weeks after the last application, was still giving over a 95% control. This corresponded to a figure of 10 mites per 30 leaves on the azinphos-methyl plots and 1135 mites per 30 leaves on the unsprayed control, and compared favourably with two sprays of demeton-methyl applied on 29th May and 22nd July.

The results of a similar trial also carried out at Rowhill Experimental Farm, but using a lower rate (0.1% formulated product) are given in Table 4.

Table 4 A 4 x replicated trial against fruit tree red spider mite

Spraying dates: 3rd and 30th June, 24th July.
Volume: Approximately 200 gallons per acre.
Results (expressed as the mean number of mites per 25 leaves)

Material	10th June	24th June	8th July	15th July	20th Sept.
Azinphos-methyl 20% Emulsion (0.1% product)	1.5	5.0	0.25	4.5	94
Control	75.0	83.0	373.0	325.0	4382

Further trials were carried out in 1960 on the effect of a single spray of azinphos-methyl on red spider populations. In one of these a spray applied on 30th June, using a rate of 3 pints in 20 gallons per acre, kept the population at a low level for the rest of the season, and on 9th September there were only 49 mites per 100 leaves on the treated plots; on the unsprayed plots there were 513 mites per 100 leaves. 1960 was not, generally speaking, a year when red spider was particularly troublesome, and normally one would not rely on a single spray, even where a petal fall acaricide has been applied.

However, azinphos-methyl is normally recommended specifically against Codling moth, and its function against red spider is regarded as secondary. Usually an acaricide such as demeton-methyl would be applied where necessary for the petal fall spray, followed by azinphos-methyl at

the normal codling timing, which has been found to give an adequate control of red spider under most conditions. For instance, in a field trial carried out in Kent during 1960, where azinphos-methyl was applied at the normal timing for codling moth control, using a rate of 0.15% formulated product, a count taken at the end of August showed a population of only six mites per 100 leaves. This compared favourably with a demeton-methyl/DDT mixture applied at the same timing.

Azinphos-methyl is primarily effective against the active stages of red spider mite and whilst having a slight ovicidal effect against the summer eggs, is ineffective against the resting stages. This should be borne in mind when spraying against codling because the correct timing for codling may not always coincide with maximum red spider activity.

THE PROBLEM OF RESIDUES

The fact that the penetration of azinphos-methyl into plant tissues is limited would indicate that the risk of toxic residues at harvest is slight, which is supported by the residue analyses given in Table 5.

Table 5 Results of residue tests using azinphos-methyl at 0.05% active ingredient

	Date of Spraying	Date of Harvest	Date of Analysis	Residue p.p.m.
Worcester Pearmain	22.6 and 14.7.59	20.8.59		0.18
Newton Wonder	22.6 and 14.7.59	18.9.59		0.05
Worcester Pearmain	13.5, 9.6, 30.6 and 22.7.59	22.7.59 29.7.59 5.8.59	28.7.59 4.8.59 12.8.59	0.74 0.18 0.12
Cox's Orange Pippin	13.5, 9.6, 30.6 and 22.7.59	22.7.59 29.7.59 5.8.59	28.7.59 4.8.59 12.8.59	0.57 0.28 0.19

On the basis of these and other residue data, azinphos-methyl has been approved by the Ministry of Agriculture's Notification Scheme for use on apples and pears provided that an interval of three weeks is allowed between the last spray and harvesting. On apples up to five applications may be made and on pears three applications, each not exceeding $7\frac{1}{2}$ oz per 100 gallons of the active ingredient high volume (0.05%).

If applied medium or low volume the quantity of active ingredient used per acre should not exceed that which would have been applied high volume. Azinphos-methyl is included in the Agriculture (Poisonous Substances) Regulations as a Second Schedule, Part III Substance.

RECOMMENDATIONS FOR THE USE OF AZINPHOS-METHYL

From experience both in trials and commercial practice the following recommendations are made for the use of azinphos-methyl.

Two applications at a rate of 0.04% active ingredient ($1\frac{1}{4}$ pints per 100 gallons water high volume or $2\frac{1}{2}$ pints per acre low or medium volume) should be made, the first made about mid-June, followed by a second in early July. A third spray may be applied towards the end of July or the beginning of August to control late attacks of codling and tortrix but whether or not this last spray is necessary can only be determined by local observation. Although this programme is directed specifically against codling and tortrix moths, it will also keep red spider populations at a low level in most seasons, following a petal-fall acaricide where necessary.

It has been said that 'a chemical is as good as its coverage' which is particularly true of non-systemic materials such as azinphos-methyl. Good coverage is, of course, important for the control of codling and even more so for tortrix, but is probably most important in the case of red spider mite where isolated colonies which have been missed during spraying can be responsible for reinfesting a whole orchard.

Azinphos-methyl is suitable for high and low volume application and good results have been obtained with both, although volumes below 20 gallons per acre are not recommended for the margin of error is much greater with this rate of application.

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OBSERVATIONS ON THE PERIOD AND DENSITY OF OVIPOSITION AND APPLE ENTRY BY CODLING MOTH IN RELATION TO TIMING AND APPLICATION OF PHOSPHAMIDON, ETHION AND DDT

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Introduction

Codling moth has always been a pest of sporadic importance in England. To some extent this variability has made it more difficult to control adequately than if it were as continually serious as it is in many countries with warmer climates. The English grower has never been convinced that a continuous routine spray programme to cover the whole flight period is necessary or economically sound, and for this reason the timing of such sprays as he has used have been the more important. Nevertheless, very little quantitative information has been published on the factors relevant in this country. When experiments were started at Ongar on the control of codling moth, firstly with phosphamidon, and later with ethion, considerable emphasis was therefore placed on obtaining basic information on emergence, flight periods, and oviposition of this pest and how these were related to the progress of the actual damage on the tree. One of the aims was to determine the importance of the early flights of moths in relation to the total level of the attack, but it was soon apparent that the known techniques of studying the progress of the attack on the apples were unsatisfactory. Not the least of the difficulties was the relatively low incidence of the attack at any one time. For example, even in an orchard where almost 50% of the apples were eventually attacked, the incidence of eggs on the apples at any one time was in the order of 2 - 3%. In the course of the insecticide experiments it was therefore necessary to explore various evaluation techniques for measuring the time and density of codling moth attack, and this paper is a progress report of the results obtained so far in this part of the investigations.

Experimental methods

Plot layouts and spray applications

Experiments were confined to the apple varieties Worcester Pearmain and Cox's Orange Pippin. Plot sizes varied from year to year depending on the number of treatments to be tested and the size of experimental plots available. On all sites randomised block layouts were used, usually with 2 or 3 trees per treatment plot with 3 or 4 replicate plots per treatment. All sprays were applied at high volume (200 - 250 gal/acre) with hand lances.

Observations and Assessments

a) Moth trapping. In 1960 a light trap was used at Ongar only and was examined daily over the period 17th May to 3rd August 1960. In 1961, in addition, two other traps were operated, at Beltring in Kent and at Bore-

ham in Essex. The trap at Ongar was emptied daily, and the others three times weekly over the period 1st June to 26th October 1961.

b) Observations on the emergence and oviposition of captive moths

Hibernating larvae were collected from the 1960 experiments and kept in gauze covered tins in a sheltered place on the boundary of one of the orchards at Ongar. These tins were observed daily from the beginning of June and when the moths emerged they were placed in sleeves on trees to observe the oviposition times and subsequent hatching.

c) Observations on egg deposition and hatching

In an endeavour to find out more about the periods of incubation of codling eggs, specific fruits or fruit clusters were marked on selected trees on each experimental site. These trees were known as 'Pilot trees'. 20 fruits on each of 8 trees were tagged on the 1960 site and 30 fruits on each of 8 to 12 trees on both sites of the 1961 experiments. These fruits were selected well in advance of the onset of egg laying and examined every other day over the period of attack. As soon as eggs were seen on these apples they were recorded and marked, and kept under observation, until they had hatched. The appearance of 'stings' on the fruits, whether associated with specific eggs or not was also recorded.

d) Observations on the progress of codling attack

As soon as eggs were observed on pilot trees, routine assessments were begun on all treatment plots. This involved examining 50 fruits per tree, taken at random, and recording the number of eggs, hatched and unhatched, and the number of stings present on this 50-fruit sample. The intention was to carry out this assessment weekly until harvest. Some counts were missed but there were sufficient on each site to enable us to deduce the periods of attack.

e) Counts of fallen fruit

Many fruits fail to reach maturity and fall before harvest. As some of these may be damaged by codling moth larvae, all fallen fruits were picked up from under each tree each week and examined for codling damage.

f) Harvest records

All fruits remaining on the tree at harvest were picked and the weight of the total yield recorded. A half bushel sub-sample was then taken from each tree and each fruit examined for codling damage and the number of fruits counted to determine the total number of fruits at harvest and the number and percentage of fruit attacked by codling.

Table 1 Relation between flight, oviposition and egg hatch of Codling Moth, 1961

Observation	Site	June week commencing:-				July			
		4 M. W. F.	11 M. W. F.	18 M. W. F.	25 M. W. F.	2 M. W. F.	9 M. W. F.	16 M. W. F.	23 M. W. F.
Emergence of captive moths	Ongar, Essex.	1	5	6	8. 8. 6.	20			
Nos. of moths trapped	Beltring, Kent.	3	1	2		3. 2.	7. 4.	4	1
	Boreham, Essex.					1	1	3	1
	Ongar, Essex.				2	6	2. 3.		
Nos. of newly laid eggs per observation	Southfleet* Kent.		2	1	2 3		3	3	
	Boreham** Essex.				5	3. 2.			
Nos. of newly hatched eggs per observation	Southfleet Kent.				2	1	5. 3. 5.	1. 1. 3.	3. 2. 1.
	Boreham, Essex.				1	1. 2. 7.	2. 2. 1.	1	

Codling moths were also trapped 2nd August (one), 16th August (one).
One 'second generation' captive moth emerged - September 7th.
Observations on eggs stopped on the 31st July.

* from 360 apples
** from 240 apples

Table 2 Incubation period of Codling Moth eggs in the field (1961)

Site:- Southfleet, Kent. Variety:- Worcester Pearmain

Egg No.	Date found	Incubation period in days
1	19 June	10 - 13
2	30 "	6 - 12
3	30 "	10 - 13
4	30 "	6 - 12
5	3 July	11 - 16
6	3 "	9 - 13
7	10 "	14
8	10 "	12 - 13
9	10 "	14
10	10 "	15
11	21 "	12 - 13
12	21 "	12 - 13
13	21 "	9 - 12

In 1960 of 15 eggs observed at weekly intervals, none took less than 7 days or more than 15 days to hatch.

In 1961, in daily observations on a batch of 15 eggs laid on the night of 17th June at Ongar, one hatched after 11 days, 6 after 12 days, 8 after 13 days.

Table 3 Relation between oviposition, egg hatch and progress of attack on the fruit

Site, Pearsons Green, 1960. Variety: Cox.

	Records from** 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 18th	-	-	-	-	-
June 25th	5	-	-	-	-
July 2nd	4	2	1.6	0	0.2
July 9th	4	5	-1.1	0	-0.2
July 16th	4	4	0.2	0.4	0.8
July 23rd	3	2	1.9	0.4	1.0
July 30th	10	2	2.4	-0.4	0.8
Aug. 6th	1	12	1.8	1.2	0
Aug. 13th	0	8	4.6	0.5	1.2
Aug. 20th	0	0	2.3	0	5.7
Aug. 27th	0	0	7.5	2.1	0.7
Sept. 3rd	(2)*	-	2.1	1.8	0.3
Sept. 10th	-	-	10.3	1.1	1.7
Harvest date - 15th	-	-	13.3	2.4	10.6
	Total at harvest		47.8	9.5	19.1

* This figure from random counts on control plots. There was clear evidence of egg laying at this level on all plots this week.

** From 160 apples.

Table 4 Relation between oviposition, egg hatch and progress of attack on the fruit

Site, Southfleet, 1961. Variety: Worcester Pearmain

	Records from* 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 16th	2	0	-	-	-
June 23rd	1	0	-	-	-
June 30th	5	2	-	-	-
July 7th	3	1	0.8	1.5	0.3
July 14th	3	13	4.3	0.9	1.4
July 21st	3	5	-0.9	0.5	-0.7
July 28th	0	6	7.0	-0.4	2.7
Aug. 4th	0	0	5.7	1.6	0.6
Aug. 11th	-	-	7.0	1.1	0.5
Aug. 18th	-	-	1.2	0.2	0
Harvest date - 25th	-	-	0.7	1.6	0.6
	Total at harvest		28.1	7.0	4.9

* From 360 apples

Table 5 Relation between oviposition, egg hatch and progress of attack on the fruit

Site. Boreham, Essex, 1961. Variety: Worcester Pearmain

	Records from* 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 16th	0	0	-	-	-
June 23rd	0	0	-	-	-
June 30th	5	1	0	0	0
July 7th	5	10	0.5	0.5	1.1
July 14th	0	5	0.3	-0.5	-1.1
July 21st	0	1	0.9	0	0
July 28th	0	0	2.4	0	1.1
Aug. 4th	0	0	3.8	0.6	0
Aug. 11th	0	0	0	0.4	0
Aug. 18th	0	0	0.5	0	0
Harvest date - 28th	0	0	2.2	0.5	0
		Total at harvest	9.9	1.6	1.1

* From 240 apples

Table 6 Proportion of codling infected apples falling before harvest 1959-61 on control plots

Site & Year	Variety	Infected apples dropped before harvest as % of total	Overall % infection
Beltring 1959	Cox	3	18
	Worcester	6	9
Pearson's Green 1959	Cox	23	47
1960	Cox	11	42
Southfleet 1960	Worcester	10	19
1961	Worcester	25	28
Boreham 1961	Worcester	7	11

Discussion

a. Flight periods, oviposition and egg-hatch

Full data on the relationship between these are only available from the 1961 experiments. It was unfortunately not possible to obtain comparisons between moth trap records and egg counts on the tree within particular orchards. On one of the two sites where moth traps were placed, there was no visible codling moth attack, even though there was a relatively high catch of moths in the trap, and in the other the yield of moths was relatively low. However, when the frequencies of moth catch from all the traps are compared side by side, as in Table 1, a similar pattern is shown throughout, and this is in itself in close relation to the oviposition data and the observations on the emergence of moths from captivity at Ongar. The egg hatch observations were a more reliable measure of egg oviposition than the oviposition observations, as several eggs were first recorded some days after they had been laid. This is because changes in the eggs in the later stages of development make them much more conspicuous on the apple surface. One obvious weakness of the oviposition observations is that they relate to eggs laid on the apples only. This limitation was deliberate, as it was thought that it would be difficult to follow the subsequent history of eggs laid on the leaves, but in practice it was found that this difficulty also applied to eggs laid on the apples, and a very small proportion of the larvae hatched from them actually entered the apples on which the eggs were laid. There is some evidence that the natural tendency of the larvae to wander before entering was increased by the handling that the marked apples inevitably suffered. There was a closer quantitative correlation between density of eggs and stings on the random samples, but in this case there is no way of relating individual 'stings' and eggs. It is also not possible from these counts to say what proportion of the stings arose from eggs laid on the apples, and what

proportion from eggs laid elsewhere, as the random egg counts at each time included eggs from the previous count. As taken in the field, random egg-counts can only give crude estimates of peak egg population, and have been omitted from the tables. Methods of extracting more precise information from such counts are under investigation and it seems that they could be made to yield valuable data on the effect of treatments on oviposition, egg hatch, and larval entry in orchards with a sufficiently high incidence of codling moth.

b. The incubation period

One of the objects of the observations on marked eggs on the pilot trees was to obtain an estimate of the average hatching period in the field. Results for 1960 and 1961 are given in Table 2. The range given for the incubation period in this Table represents the interval between successive observations on each egg. For the later observations in 1961 it was possible to reach a more precise estimate by studying the development stages. In general the incubation period was 10 - 24 days.

c. Relation between oviposition egg hatch and progress of the damage on the apples

Although the dates of oviposition are the best measure of the beginning of the attack, the hatching date is most relevant to spray timing. If the incubation interval is 10 - 14 days, sprays which are applied at flight time or oviposition time are likely to be well diluted, perhaps by weather and certainly by apple growth, by the time the eggs actually hatch. The observations in 1961 suggest that the earlier part of the June attack was making a very small contribution to the total attack and that the main onset of egg hatching was 2 - 3 weeks after the very first moths were trapped. On this basis sprays applied too early in June would not only have a small effect on subsequent attack, but if normal spray intervals were adhered to, would result in minimum protection being available at the most important time. However, the egg counts can only give a qualitative picture. The next essential step is to estimate what proportion of the damage can be associated with any particular flight or hatch period. To do this the progress of the attack on the apples themselves has been estimated from the following data:- (a) the level of infection on the tree by sample counts at weekly intervals; (b) the numbers of dropped apples per week; (c) the numbers of dropped infected apples per wee; and (d) the numbers of clean and infected apples at harvest.

From these the level of infection in terms of total apples produced can be calculated.

These calculations for those experiments where all this information is available are given in Tables 3, 4, and 5. These experiments have been primarily concerned with ethion in various spray combinations, but there is not the space to give all the details of this work here. Instead, the results of the controls and standard treatments are given to show how this approach indicates clearly where a particular treatment is failing to give complete control. In these tables the oviposition and egg-hatch data are included to show how these are correlated. In all these there is a lag of

about one week between peak egg-hatch on the pilot tree and peaks of apple entry on the main plots. This is because 'Stings' are generally not detected under conditions of large-scale random sampling until they are a few days old. The results from all three sites are in agreement in that the proportion of attack taking place before the end of June is negligible. On the 1961 sites, both on Worcester, the greater part of the fruit entry was observed in the last week of July and the first week of August, which, allowing for the time lag in detecting stings, coincides with the peak of egg hatch on the 10th - 21st July, and of oviposition from the 26th June to the 7th July, shown in the observations on the pilot trees. On the 1960 site the pattern was very different, the oviposition egg hatch show three peaks, one from the 15th June to the 3rd July, one from the 17th July to the 31st August, and another very late peak at the end of August. The peaks of damage detection each follow at about three-week intervals after these oviposition peaks. The increases in infestation close to harvest may partly be due to second entry. Attempts were made to distinguish between this and primary attack but were not successful on a routine basis. The very late attack on the 1960 site is, however, almost certainly due to the partial second generation as eggs were known to be laid at this time. It accounted for 20 to 30% of the total final infestation. In two of the sites there is a slight fall in the percentage infection at the end of June: this is known to have been associated with 'June drop'.

d. Timing and efficiency of the treatments

In 1960, both of the standards in these experiments, DDT and phosphamidon, were applied as conventional three application programmes at three intervals of three weeks from the 15th June to the end of July. In 1961 the number of phosphamidon applications was increased to four but covered the same spray period. From Table 3 - 5 it is clear that although the degree of control was satisfactory, a better result might have been obtained by delaying the programme by about a fortnight throughout, i.e., delaying the first spray until the last week in June. As it was, the last spray was not applied late enough to catch the most important phase of the attack, i.e., from mid-July to mid-August. In terms of proportion of crop saved, the first application was largely wasted. DDT and phosphamidon were similar in efficiency. Another point of practical importance is that most of the apples attacked early on drop before harvest. Although they represent a loss of crop they are less costly to the growers than those apples which contain codling at harvest and have to be picked out on the grading table. Most of these latter will have arisen from the August attack. Table 4 shows the proportion of infected apples that dropped before harvest on a number of sites from 1959-61. The proportion is very high - frequently more than half - and demonstrates that the considerable labour of gathering the dropped apples week by week cannot be avoided.

Too many generalisations on spray timing should not be made from the results from three sites in two years, and it must be remembered that the first larvae to enter the apples are especially important in that they

are the source of the second generation attack in late varieties of apples. A substantial second generation did occur at one site, but this experiment could not detect any treatment effects, as there were always sufficient early-maturing larvae from the untreated plots to provide enough second generation moths to give rise to a high level of infection on all treatment plots.

Conclusions

Several points have arisen from the work so far which might be considered in evaluating the efficiency of insecticides against this pest. These are:-

1. That harvest data alone cannot provide an adequate method for comparing the efficiency of different spray timings.
2. That it is possible to follow the progress of the attack quantitatively and so to estimate the direct effect of a particular application.
3. That using such methods it could be shown on these three sites that:-
   a. less than 2% of the final attack could be attributed to eggs hatching before the end of June.
   b. At least 50% of the attack arose from eggs hatching between mid-July and mid-August.
   c. The one example of second generation attack arose from eggs hatching in early September.

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LEAF BRONZING IN APPLES AS A MEASURE OF EFFICIENCY OF ACARICIDES AND ITS RELATION TO LEAF POPULATION OF FRUIT TREE RED SPIDER

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Introduction

Dr. Massee in his survey of the red spider problem in 1949 (Groves and Massee 1949) said that one of the difficulties of experiments on the control of red spider was the measurement of the degree of control. This was perhaps more acute at that time when the control of summer infestation depended on the use of pre-blossom treatments. Since then the widespread use of summer acaricides has made it possible to obtain immediate control of the summer population but it is still not easy to get an accurate quantitative picture of the overall effect of an acaricide throughout the season. The chief reasons for this are:- (a), the population of red spider throughout the summer period fluctuates because of the succession of generations, but the effect on any one of these generations cannot be measured very clearly because, as shown by Blair and Groves (1952), two are normally present at any one time. Furthermore, one of these generations may be present at the egg stage and the immediate effect of the acaricide on the population is not necessarily a good measure of the subsequent effect on the build-up. (b), Red spider does not have any direct effect on the yield of crop nor on the appearance of the fruit itself, so that neither can serve as a measure of the degree of control. The magnitude of the indirect effects on yield, resulting from the characteristic leaf damage is inevitably influenced by environmental conditions, tree vigour and variety so that it is hardly surprising that results from different sources have often been conflicting.

Of course, it is quite possible to follow the fluctuations of population accurately as Blair and Groves did by sample counting at intervals on both treated and untreated trees, but apart from the labour involved in doing this on a large number of treatments, it is not easy to express the differences in population fluctuations in a simple comparative way. Even if one is able to detect differences in the population density over a given time one may not know what these mean in terms of damage to the tree and therefore it becomes difficult to put treatment differences in perspective. Many attempts have been made to establish the relationship between red spider attack and yield, but, apart from the general failure so far to establish a clear relationship, the majority of summer insecticide programmes designed to control red spider mite will also be affecting other pests and diseases, and so influencing yield. This was certainly true of two of the insecticides we were interested in, phosphamidon and ethion, both of which were being tested primarily for their effect on codling moth. The only visible damage which is a characteristic of red spider is the

'bronzing' effect caused by the feeding punctures on the leaf. In the course of our work on red spider we have attempted to relate the intensity of damage with the population density throughout the season and by this means establish the practical importance of observed treatment differences.

Methods

A. Population Counts

The population levels have been estimated from leaf samples taken at intervals through the summer. The distribution of red spider changes progressively through the season and the attempt has been made to overcome this by a partially systematic sampling technique. Pairs of leaves are taken from 5 random trusses on each of three branches, each pair of leaves consisting of one of the small older leaves, and one of the later full sized leaves. This is because the attack normally starts on the older and smaller leaves and eventually spreads to the younger leaves. Extension shoots are avoided, partly because the red spider often does not reach these until very much later in the season, and partly because it is much more difficult to operate a routine sampling method which includes both extention shoots and leaf trusses without taking inordinately large samples of leaves. In most of the experiments described here, 30 leaves were taken per tree, usually from 2 trees per plot, the replicates varying from 3 to 6. In all experiments but one in this paper the total leaf sample per treatment was 180.

Extraction of the mites has not been by the classic East Malling method (Austin and Massee, 1947) but by a method derived from a technique described by Melvin and Earle (1948) for another purpose. Briefly, the leaf samples are picked directly into conical flasks, and a band of softened petroleum jelly smeared around the inside of the neck of the flask immediately after collection. The flasks are, as soon as convenient, placed on a warming mat under fluorescent light and as the leaves dry out the mites leave them, climb the sides of the flask and become embedded in the band. They can easily be counted in this position, and different stages of the active mites are easily distinguished. The main advantage of this method over the leaf-pressing method is that it is easier to operate when examining a large number of treatments and replicates on a number of sites, with relatively unskilled or inexperienced operators. The main disadvantage is, of course, that it only extracts the active stages although there is some evidence that some egg hatching does take place during the extraction process. The extraction efficiency has been checked by comparison with a formalin washing method.

On the whole, flask extraction has given a rather higher count of newly hatched nymphs than the formalin method, mainly due to hatching after collection, but a lower count (50 - 60%) of adult mites. However, as the major population surges seem to be chiefly due to the egg-hatching of young nymphs, these weaknesses do not prevent the method from giving a reasonably accurate assessment of the population fluctuations.

Ideally, counts should be carried out weekly from petal-fall until

October but this has been rarely practicable and a much longer interval has been used in the early part of the season, when population levels are generally low.

B. 'Bronzing' assessment

A simple five grade (0-4) scoring system was used, but as two or more observers independently graded each tree in each replicate, the mean treatment score was derived from 12 - 24 observations and a finer gradation of means was possible. The grades used were:-

Grade of damage	Score	Range of means	Description
V. severe	4	3.5 - 4.0	Bronzing complete - no green colour visible.
Severe	3	2.5 - 3.5	Nearly complete but a significant proportion of green leaves visible from a distance.
Moderate	2	1.5 - 2.5	General effect green but some bronzing can be seen from a distance without difficulty.
Slight	3	0.5 - 1.5	Leaf damage not at the bronzing stage and can only be detected by closer examination.
Negligible	0	0 - 0.5	No damage visible.

It is essential that the damage score should be made while the leaves are still green and vigorous on unattacked trees. Immediately after picking has been found to be a suitable time for the common commercial varieties. This has the advantage that differences in fruit density and colouring do not influence the assessment.

Results

A. Population fluctuations as a measure of control

Figure 1 gives typical population curves for the controls and treatments on one site in a series of experiments in 1959. (This is part of the experiment given in more detail in the tables). These curves exhibit the same sort of fluctuations due to the overlap of the generations as shown in Blair and Groves' work, and illustrate how a severe late summer attack can build up even from a low petal-fall population. The relation between the control and treatment curves in these figures reveals the difficulty of estimating the degree of control obtained for the comparison of the effects of treatments. The possibility of expressing the intensity of mite attack by an estimate of the area under the population curve has therefore been examined. This gives a measure of the 'mite-days' to which a particular leaf sample is exposed to attack. The measure of intensity of attack ob-

tained by this method is illustrated in Table 2. One of the drawbacks of a method of this type is that treatment differences are apparently exaggerated and it becomes more difficult to judge the practical significance of the values obtained.

B. Comparison of 'mite-days' and 'bronzing' methods

Although both methods have been used in all our acaricide work since 1958, the comparison of these two methods is best illustrated by an experiment carried out in 1959 on four sites, two each of two varieties, and in which the treatments, the times, and methods of application, and the times and methods of assessment were exactly the same on each site. This experiment was primarily designed to give information on the control of codling moth, but the control of red spider mite was an important secondary issue. The results obtained by the two methods are compared in Tables 1 and 2.

Table 1 Comparison of treatment ranking by population counts and by 'bronzing' score

Experiment No. 59/18/16

(a) By Mite days

Variety	Site	Treatments in descending order of effectiveness							
Worcester	Horsmonden	5	6	3	1	4	2	7	8
	Beltring	5	3	6	4	1	2	7	8
Cox	Matfield	5	6	3	1	4	2	7	8
	Pearson's Green	5	6	1	3	4	2	7	8

(b) By 'Bronzing' Score

Variety	Site	Treatments in descending order of effectiveness							
Worcester	Horsmonden	1,5,6.			3	2,4		7	8
	Beltring	1,5		3,6		4	2	7	8
Cox	Matfield	5	1,3		6	4	2	7	8
	Pearson's Green	1,5		3	6	4	2	7	8

Table 2 Actual values of Mite days and 'bronzing' score for four treatments of practical interest from Table 1

(a) Mite days

Site	Mean log mite days per 30 leaf sample (Mean of 6 samples) Figures in brackets are actual mite days per leaf				S.E.* of a treatment mean (log mite days)
	5 Ethion 2 x 0.05%	1 Phosphamidon 4 x 0.02%	7 DDT + chlorbenside	8 Control	
Horsmonden	1.91 (2.7)	2.92 (27)	4.02 (352)	4.09 (414)	+ - .168
Beltring	1.11 (0.4)	3.23 (57)	3.57 (127)	4.23 (566)	+ - .171
Matfield	1.10 (0.4)	2.85 (24)	3.49 (103)	3.80 (211)	+ - .167
Pearson's Green	0.92 (0.3)	1.82 (2.2)	3.21 (193)	3.80 (211)	+ - .248

(b) 'Bronzing' score

Site	Mean 'bronzing' score (Max = 4) Mean of x 3 replicates x 2 observers				
	5 Ethion 2 x 0.05%	1 Phosphamidon 4 x 0.02%	7 DDT + chlorbenside	8 Control	S.E.* of a treatment mean
Horsmonden	0	0	1.83	2.33	+ - .137
Beltring	0	0	1.25	2.33	+ - .314
Matfield	0	0.17	1.50	2.25	+ - .256
Pearson's Green	0	0	1.58	2.42	+ - .314

* S.E. calculated from all eight treatments in Table 1

Table 3 Relationship between 'mite days' and level of 'bronzing'

Variety & Site & Year	Mite days per leaf causing damage at a particular level of 'bronzing'			Mean mite days per leaf*	Max. mite Nos. per leaf	Bronzing score
	Slight	Moderate	Severe			
Worcester Pearmain						
Horsmonden 1959	224	490	1096	414	9.4	2.3
Beltring 1959	182	490	1349	566	21.6	2.3
" 1958	78	219	549	410	30.5	3.3
Cox Orange Pippin						
Matfield 1959	97	281	871	211	11.7	2.3
Pearson's Green 1959	35	218	1148	211	8.3	2.4
Ongar 1958	39	87	229	430	35.1	3.7

* Geometric means

The first aim of this comparison was to see whether bronzing score would place treatments in the same order as the more time-consuming mite counts, and with a sufficient degree of precision. In Table 1 is seen the ranking of the eight treatments in the experiment as given by the two methods on the four sites; the order of ranking by the two methods is in close agreement. In order to show the practical significance of the order of ranking, Table 2 gives the actual values obtained for phosphamidon, ethion, DDT and the controls. In these two Tables one can see that the 'bronzing' method has given the same practical answer as the count method and although the precision is less it is in fact sufficient to enable one to assign a practical value to the treatment differences with some degree of confidence. The complete analysis shows that, as would be expected from a log transformation, the 'mite-days' method tends to give a better separation of the more successful treatments than the less successful. On the other hand, the 'bronzing' method is less able to distinguish between low levels of damage, and is more effective when the treatments are less successful.

C. Relation between 'mite-days' and bronzing

Similar close agreement between treatment ranking by the two methods had been obtained on two independent sites in 1958 (the first on which the 'bronzing' method was used), and suggested that a quantitative relationship between the two rankings might be found. Figure II shows a straightforward plot of mite-days against bronzing score. The agreement between these two curves encouraged fuller study of the method, mainly to see whether it would serve for measuring treatment differences on a large number of sites, but also to see whether a quantitative relationship could be established between the intensity of mite attack and the characteristic

symptoms by which the grower normally judges the efficiency of these control measures. The 1959 curves differed to a certain extent from those for 1958 and various transformations were tried to make the data easier to analyse. The most satisfactory method so far found has been to express 'bronzing' score as a percentage of the maximum possible score, transform to probits and plot against the log of mite days.

The chief requirement for an examination of relationship between these two methods is that the experiment should contain sufficient treatments of only moderate success to give a wide range of 'bronzing' responses. Probit regression lines for three crops of Cox and three crops of Worcester, on which there was sufficient variation in 'bronzing' are given in Figure II. It will be seen that the form of the relationship is similar in each case, but that there are pronounced quantitative differences from site to site and year to year. These differences are shown more clearly in Table 2 where they are expressed as the level of 'mite-days' per leaf which has resulted in damage equivalent to the means of the three damage categories, slight, moderate, and severe damage. The fiducial limits of the lines have not been calculated, but there is sufficient agreement between them to suggest the following points: (1), it required a higher intensity of mite attack per leaf to produce the same degree of bronzing on Worcester as on Cox; (2), the same level of mites produced a much higher degree of bronzing in 1958 than in 1959. The actual values for the control plots in each year are given, and these show marked differences from the relationships measured from the whole of the experiments. They also show, however, that there was a tendency for a higher level of attack to be maintained on the Worcester than on Cox so that the final damage was similar in the two varieties. A possible explanation lies in the very high August levels of population in 1958, and there are undoubtedly considerable climatic differences between the two years which could account for different levels of damage. One must admit, however, that there are differences in interval between scoring and counting which might also provide some of the answers. The effect of high late season levels illustrates one of the weaknesses of the bronzing method as an absolute method of intensity of mite attack throughout the season. In this past year only one experiment has been carried out to which these methods could be applied. Red spider attack developed exceptionally early in high numbers, and in order to avoid complete defoliation of the trees the controls and DDT plots had to be sprayed with an acaricide in the middle of July. All plots remained free after that date; this means that in contrast to the experiments so far described, the major part of the mite attack on this site was before mid July instead of after it. It is perhaps significant that on this site low levels of bronzing were obtained even with relatively high mite counts. Probably the leaf bronzing in June or in early July, which was very apparent this year, was considerably masked later by new growth.

More work is needed to establish the relative parts played by late and early attack. The effect of growing conditions and variety are also important. In 1958 one crop of Laxtons Superb was examined by this method

and gave a regression line of markedly different slope from that reported for Cox and Worcester. However, it does seem that 'bronzing' assessment can be a rapid and effective means of comparing the efficiency of acaricide treatments quantitatively. If one did not wish to rely upon it entirely, much counting could be avoided by using the counts from controls and one or two of the less efficient treatments, to establish the 'bronzing'-mite days relationship for each site.

Acknowledgements

My thanks are due to numerous colleagues who have assisted in assembling data on which this paper is based.

I would especially like to mention Mr. D C. Twinn and the members of his unit who carried out the mite counts, and Mrs. B.A. Bryant who undertook most of the statistical analysis.

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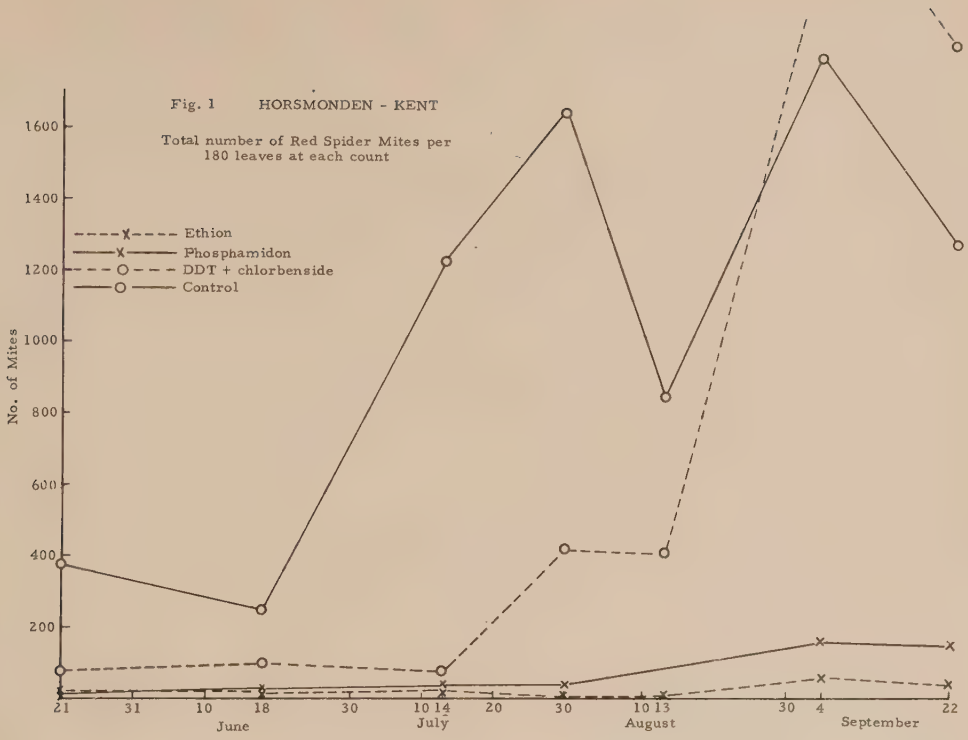


Fig. 1 HORSMONDEN - KENT
Total number of Red Spider Mites per 180 leaves at each count
Ethion
Phosphamidon
DDT + chlorbenside
Control
No. of Mites
1600
1400
1200
1000
800
600
400
200
21
31
10
18
30
10 14
20
30
10 13
30
4
22
June
July
August
September

Fig. 2 RELATION BETWEEN MITE DAYS AND BRONZING SCORE

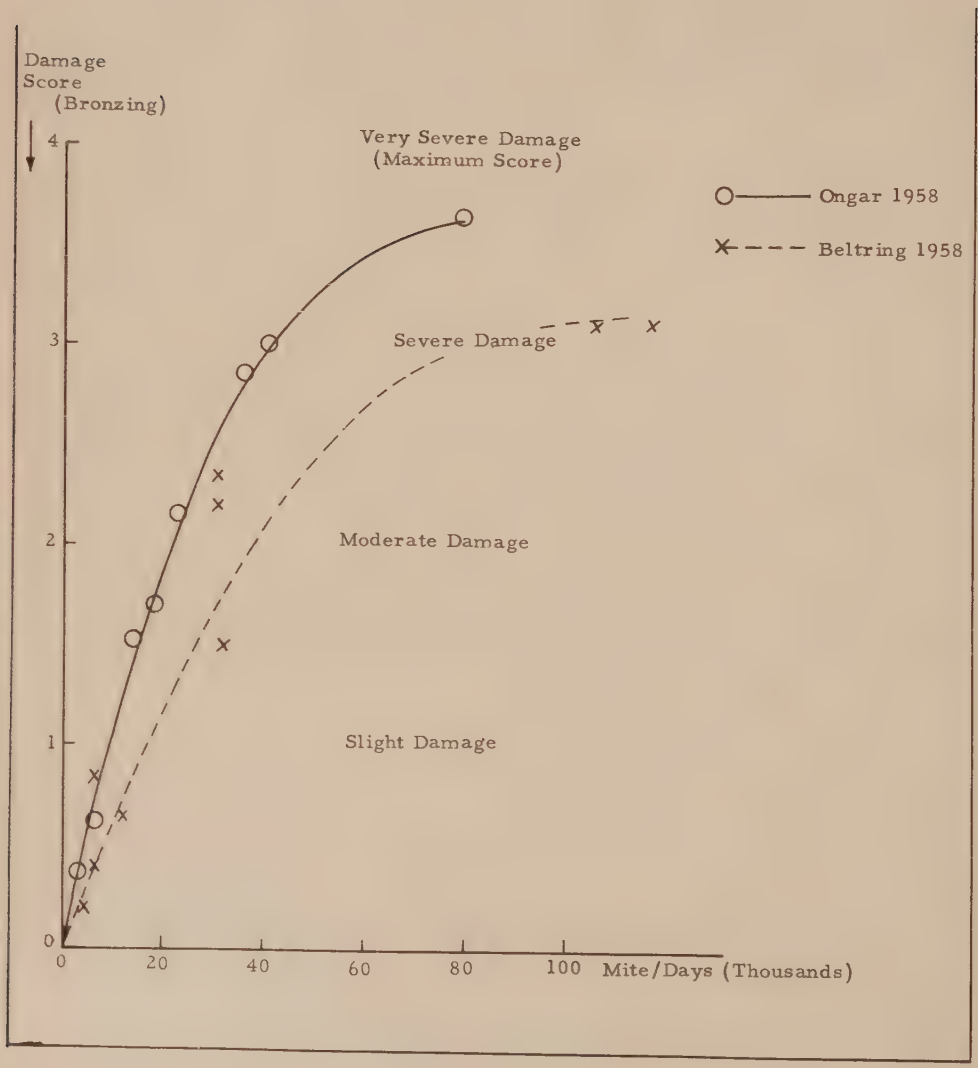
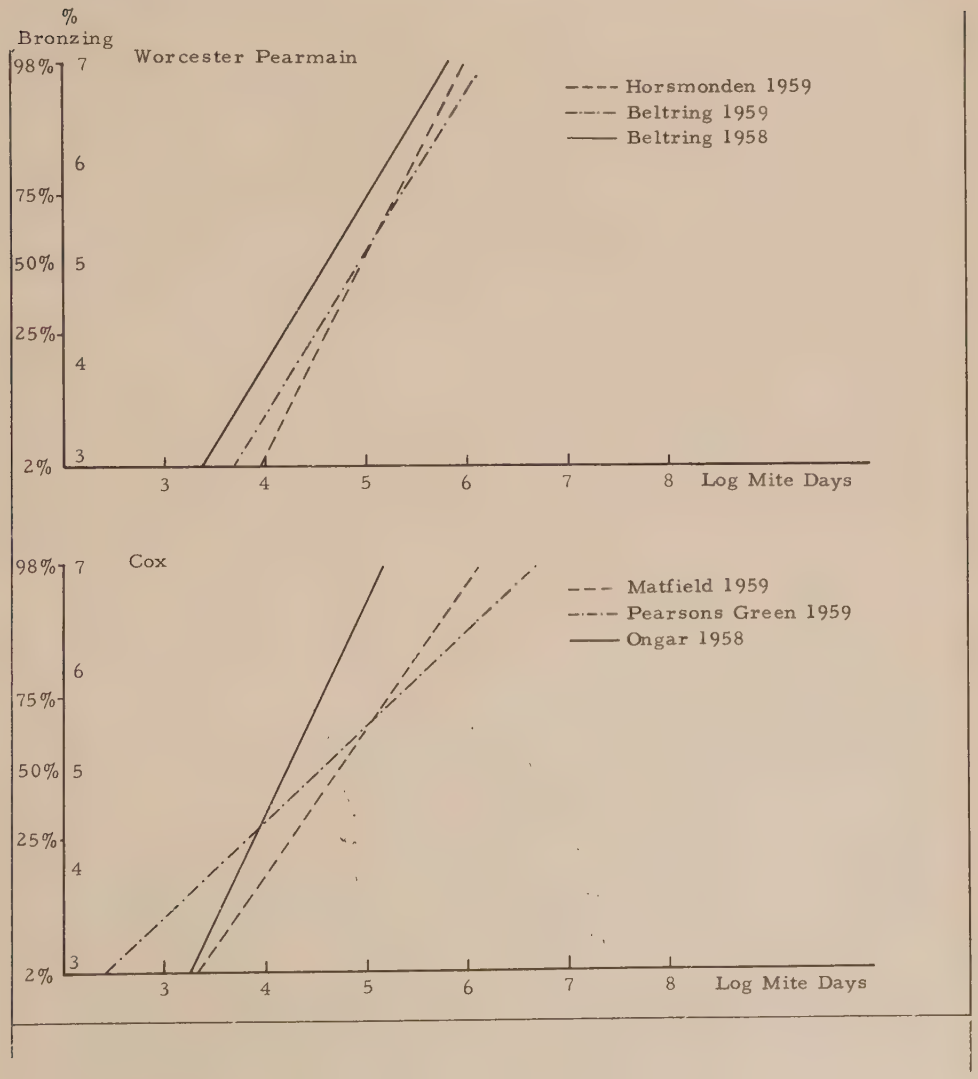


Fig. 3 CALCULATED PROBIT REGRESSION LINES

Excluding 0% Bronzing, as scoring system was such that small percentages (≏>2%) were counted as 0%.



THE PRESENT POSITION REGARDING THE INCIDENCE AND CONTROL OF APPLE APHIDS, FRUIT TREE RED SPIDER, FRUITLET MINING TORTRIX AND PEAR SUCKER

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The pattern of behaviour of insects and mites of economic importance in fruit growing is both complicated and unpredictable, a consequence of a combination of biological and ecological factors. Among the biological factors are the number of generations a year, the inherent capacity for varying resistance to toxic chemicals, and the ability to exist on several alternative host plants may decide whether or not a pest is easy to control. The ecological factors include the availability of alternative hosts, the disturbance in the balance of predator and parasite populations often caused by the use of spray chemicals, weather condition and its effect upon birds and other wild life, and various cultural practices will all effect the issue for good or ill.

Experience shows that certain pests are easy to control, and that where routine spray applications are carried out they may be regarded as nonexistent. Among these are Apple Blossom Weevil, Apple Sawfly, Apple Sucker and Apple Capsid Bug. Conversely, certain other pests must always be regarded as a serious menace in spite of the fact that they have been subjected down the years to a wide range of spray chemicals. Among these are Fruit Tree Red Spider mite, Aphids, and some species of caterpillars.

A third category will include insects which have been known to entomologists for many years, but which for reasons difficult to explain, have become more numerous, or have changed their hosts and have now become pests requiring control measures.

The writers have selected two subjects from the 'difficult to control' category viz:- Aphids and Fruit Tree Red Spider, and two from the 'new pest' category viz:- Fruitlet Mining Tortrix Caterpillars and Pear Sucker.

APPLE APHIDS

The four main species of aphids which are of economic importance are: (a) Apple-grass Aphid (Rhopalosiphum insertum), (b) Rosy Apple Aphid (Sappaphis mali), (c) Woolly Aphid (Eriosoma lanigerum) and (d) Rosy Leaf Curling Aphid (Sappaphis devecta).

Apple-grass Aphid

This aphid occurs little or much every year, the incidence varying from one or two eggs per branch to hundreds of eggs on a spur. This variation in population from year to year is no doubt due to the effect of weather and other conditions on the well being of the alternative host plants. Often the fruit buds of apple trees are completely covered with the newly hatched aphids during the 'burst' stage in March or April, Be-

fore the introduction of winter washes control was often very difficult, but with the introduction of tar oil and DNC/Petroleum Oil winter washes, complete control was invariably obtained. During the late 1940's there was a trend among fruit growers to discontinue the regular use of winter washes in favour of BHC and combined BHC/DDT sprays. These could be applied following the hatching period at bud burst, and afforded a cheaper and more convenient method of control than the winter washes.

Given ideal timing and good weather conditions, control of aphids by spring spraying has generally been good, but where the timing has been delayed, often through adverse weather conditions, the control obtained has been disappointing, particularly when low volume methods of application have been used. In recent years growers have said that control of aphids by spring spraying with BHC and DDT has been so poor that two or three applications have been found necessary. Some growers have suggested that aphids have become resistant to these chemicals but there is no evidence, apart from grower experience, to support this. It is more likely that low-volume application techniques, which have become almost universal in recent years, are not as effective as high volume drenching sprays under conditions where the aphids have been able to penetrate deeply into the bud clusters.

Economics and labour shortages prevent a return to high volume spraying and the question arises as to whether it is not better to use a more effective insecticide immediately before the blossoms open in order to obtain a complete control and avoid a carry-over of aphid populations through the blossoming period and on to subsequent growth stages. The question raises the following points (1), optimum timing between bud burst and blossom period, (2), the need to add another chemical for the control of other pests at the pre-blossom stages (e.g. DDT for caterpillars), (3), the effect on predators and parasites and the possible results of this upon the incidence and control of Red Spider at later stages, and (4), the comparative cost in relation to BHC or BHC/DDT.

In following the possible alternatives to BHC and DDT the choice will probably rest with one of the following - diazinon, phosphamidon, malathion, demeton-methyl, mecarbam and dimethoate.

In making a choice it should be noted that some of these alternatives are true systemics, and the question of whether there is sufficient leaf area on the tree before blossoming to take advantage of systemic properties will be of first importance.

Rose Apple Aphid

This is the most damaging of all the apple aphids. Like the Apple-grass Aphid, control by winter washing is usually good, but often spring spraying is unsatisfactory. Complaints have been made by many growers in recent years of successive (if sporadic) infestations throughout the summer months, too common to ignore yet hardly worth a separate spray application for their control. These local colonies of aphids breeding in curled clusters of leaves are difficult to control, and in some cases appli-

cations of some of the most recent systemic chemicals have failed to give complete control. The reason for these persistent colonies throughout the summer is most likely an incomplete control of the aphids during the pre-blossom stages. Further attention should be directed toward both choice of chemical and method of application during the early stages of growth to obtain a complete kill and to avoid further occurrences of Rosy Apple Aphid (Blue Bug) in the post-blossom period.

Woolly Aphid

While Rosy Apple Aphid is judged to be the most destructive species because of the direct damage it does in stunting and distorting the growth and fruitlets, Woolly Aphid might well be the most costly aphid to the fruit grower because of the indirect damage it causes. This damage includes the obvious stunting of growth, disfigurement of fruits and the general sticky and dirty staining effects on the clothes and bodies of workers. In addition there are the indirect results of Nectria apple cankers and a higher incidence of Gloeosporium cankers giving rise to storage rots.

Woolly Aphid has always been a difficult pest to master. While it may be given a setback and the trees appear almost entirely free, it quickly becomes re-established given favourable weather conditions. Winter washing gives some measure of control, but the present method of medium volume application by automatic spraying machines is hardly likely to be as effective as the drenching formerly given by hand application. Like the two previously mentioned species the control obtained by thorough spray application in the pre-blossom period is likely to have a profound effect upon the incidence of this pest late in the year. It should not be assumed that because no 'woolliness' is seen during the early growth stages, that Woolly Aphid is absent. High populations may be in the trees at pink-bud stage with little or no sign of 'woolliness'. Thorough spraying at this stage with a good phosphorus insecticide will hold the pest in check for a long period.

Often apple trees are found to be heavily infested with woolly aphid during the fruit harvesting time. An application of a good insecticide immediately the fruit is harvested will reduce the infestation the following spring.

Rosy Leaf Curling Aphid

This aphid often called the Red Leaf Aphid because of the bright colour taken on by infested leaves, occurs regularly in well defined localities. It is slow to spread and its occurrence is often limited to certain trees where it may re-appear year after year. The reason is that it has no migrating phase, and that its period of activity is short compared with other species. The eggs are laid by the fourth generation in early July and are deposited in well protected positions often under the bark which makes control by winter washing almost impossible.

Rosy Leaf Curling Aphid is not easy to control by spring spraying for the leaves curl at an early stage and the aphids are well protected. A systemic insecticide is necessary for a good control and both dimethoate and demeton-methyl have proved effective.

FRUIT TREE RED SPIDER MITE (Metatetranychus ulmi)

It is now evident that there is an ever increasing number of apple orchards in England where the Fruit Tree Red Spider mite are becoming resistant to the organophosphorus compounds in general and the big question is where do we go now?

This mite started to become a minor pest in the late 1920's after the introduction of Tar Oil winter washes which killed off some of its predators. However, with the introduction of DDT into orchards at the end of the war, the mite assumed the role of a major pest. When DDT is applied post blossom, the population of Black-Kneed Capsids (Blepharidopterus angulatus) is almost annihilated. Since this insect is the chief predator of the Fruit Tree Red Spider mite, it follows that the mite can build up to high numbers in a short time given suitable weather conditions.

It was known, however, that a D.N.C. petroleum wash, if properly applied just before bud burst, will give a high percentage kill of the winter eggs of the mite, and if derris was applied during the growing season, the mites which did emerge could be reasonably well controlled.

After World War II, agricultural labour was at a premium and the chlorinated hydrocarbon compounds, chlorbenside, chlorfenson and chlorobenzilate and the first organo-phosphorus compounds were found to be effective against this pest. This resulted in a swing from winter washes of any sort, and reliance on sprays applied during the growing season for control of all pests.

The use of parathion at about the petal fall stage appealed to many growers as an economic spray since it would control red spider, aphids including Woolly Aphid, and Apple Sawfly in one application. Some growers continued this for many years, often using sub-lethal doses of toxicant per acre. Other growers did not like the use of such a poisonous material and began using non-poisonous summer ovicides. This stage of affairs continued with the introduction of several alternative phosphorus compounds, such as demeton-methyl and malathion, which were used as a petal fall spray followed in late June with an ovicide spray.

Until 1958 this procedure seemed to work well, but then suspicions of resistance to the summer ovicides arose, and were confirmed in 1959. However, other organo-phosphorus compounds were discovered, some more effective than those already in use, and so the control of this pest seemed to be well in hand. But in 1960 and 1961, the mite populations in many orchards seemed to have developed resistance to the latest phosphorus compounds.

Fortunately for English fruitgrowers, this development has already occurred in parts of Europe, the U.S.A., Australia and New Zealand in the control of closely related mites (Maelzer and Loehmeyer, 1960). In these countries, resistance to the organo-phosphorus compounds, chlorinated hydrocarbons and the sulphones was known. As early as 1946, forecasts were made as to the possibility of insecticide-resistant mites (Steiner et al. 1946) but the warnings were largely unheeded.

One of the most disturbing features of the development of resistance is that it usually seems to develop slowly at first and then more rapidly. Hence a chemical which has given good control for a decade or so, may quite suddenly seem not to give economic control and a year later be quite valueless.

In these countries, it has been found that it is much better to alternate the use of insecticides, rather than to use one exclusively until resistance to it appears and then to change to another. Where possible, it is advantageous to alternate between compounds from different chemical groups.

Unfortunately in England, no sooner has one basic chemical grouping been found to be effective against Fruit Tree Red Spider mite than many slight 'variations on the theme' have quickly followed, such as in the summer ovicides and organo-phosphorus compounds. As a consequence many orchards have been sprayed at the same time with the same type of material.

Not only have these sprays been introduced for mite control but some have been found effective against and recommended for, the control of Codling Moth and various Tortrix species, necessitating the application of two or three sprays of the same material in one season.

Fortunately, we have two compounds in the non phosphorus groups which can be used as alternatives:- (1) in the sulphone group, there is tetradifon which has only been used for two or three years and which is giving a good control; (2) recent large scale trial work in England suggests that 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethanol will give good control of phosphorus resistant strains of the Fruit Tree Red Spider mite, and provides further chemical group with which to alternate.

The number of years elapsing before one can return to a particular chemical group in an orchard where the mite population has previously developed resistance to this group is not known.

Instances have occurred where the summer ovicides have been retried in orchards where they have not been used for three years and successful control has not been obtained.

How can we then use the materials available to us at the present time to the best advantage? We have five groups of materials known to be effective against the mite at some time or other:-

(1) Summer ovicides - chlorbenzide, chlorfenson, chlorobenzilate.
(2) Organo-phosphorus compounds - azinphos-methyl, demeton methyl, diazinon, dimethoate, ethion, malathion, mecarbam, mevinphos, morphothion, phenkapton, phosphamidon and parathion.
(3) Ethanol grouping - 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethanol.
(4) Sulphone grouping - tetradifon.
(5) D.N.C. petroleum washes.

The use of dinocap, another chemical group, in the fungicide programme of a dessert orchard, also gives a useful alternative.

Two suggested programmes for the next two or three years are listed below:-

1. For the majority of orchards where phosphorus resistance is not yet apparent: D.N.C. petroleum just before bud burst or a phosphorus insecticide at petal fall, and alternating with materials from groups 3 and 4 in June or July as required.
2. For the orchards in which the mite population already show resistance to organo-phosphorus compounds: D.N.C. petroleum wash just before bud burst and alternating with materials from groups 3 and 4 in June or July as required.

In further years, alternative programmes and materials can be used to make all possible trends to resistance impossible.

The programmes suggested above do not preclude the use of various organo-phosphorus materials pre-blossom for the control of aphids, which must be recommended in many years for these sprays will rarely affect the red spider mite problem. The use of phosphorus compounds after picking, say in late September - early October for Woolly Aphid control will also not greatly affect the mite population. But again, the use of alternative materials over a period of three or four years is advisable. The control of codling moth and surface eating tortrix species with phosphorus insecticides is now unnecessary with chlorinated hydrocarbon and carbamate group compounds available, and in any event phosphorus compounds should not be used more than once every five years.

By observing these simple precautions and following the suggestions outlined it should be relatively easy for English fruit growers to overcome any possibility of selecting resistant Fruit Tree Red Spider mite populations.

FRUITLET MINING TORTRIX (Pammene rhediella)

During the years 1955-58 specimens of apple fruits mainly Bramley and Laxton Superb were received showing damage indicative of feeding by caterpillars, accompanied by boring into the apple. No living insects were present on these fruits and the reason for this damage remained unsolved until the summer of 1959.

During July 1959 Mr. K. Chandler of the Land Settlement Association, Foxash, Essex, with Mr. J. Brakefield, Murphy Chemical Co. Ltd., discovered a number of lepidopterous larvae hibernating in a sacking tree band in an orchard where apples with this distinctive damage had been found. A tall hawthorn hedge surrounding the orchard carried a high population of Pammene rhediella and the larvae were suspected of the apple damage. In 1960 investigations carried out in the weald of Kent, East Sussex and Wisbech areas, showed that P. rhediella had become established in apples some distance from hawthorn, and were found damaging pears, plums and cherries. During 1961 severe infestation has been noted in orchards around Wisbech, in Somerset, Essex, Kent and Sussex. In the Isle of Grain, Czar plums were damaged. It is now safe to say that local infestations occur over most of the fruit growing areas of England and that these

can often cause financial loss to the grower.

The larvae, after feeding on the surface of the fruit and tunnelling beneath the skin, become fully fed at the end of June. They find suitable hibernating sites and spin a cocoon where they remain until the following April. From the middle of April until the end of May they are in the pupal stage and emerge as moths from the third week in May until mid June. Eggs are laid on leaves and the receptacles of the flowers of apples at about petal fall stage, and caterpillars may be found all through June until they go into hibernation early in July. The caterpillar, when fully fed, is about $\frac{1}{2}$" in length, of a greenish white colour. The head is black and anal plate brown, and there are seven black spots on each segment.

Attacks are most severe in orchards surrounded by hawthorn bushes or hedges which do not receive an annual trim. The population in hawthorn where the bushes carry a crop of haws.

Control measures in fruit trees consist of an application of DDT immediately at petal fall. The timing for sawfly sprays would be ideal for P. rhediella. For pears and plums the time to spray will approximate to the petal fall stage in apples.

PEAR SUCKER (Psylla pyricola)

Pear Sucker is without doubt the most serious pest of pear orchards in England today. It has been known for many years and sporadic outbreaks in particular orchards have been recorded. However, in the last five or six years the pest has come into real prominence. In many orchards where it had rarely been seen previously big populations soon became established. Where this menace was either not seen or else left unchecked, the insidious type of damage caused led to a marked reduction in the crop.

Pear Sucker overwinters in the adult stage, which may be found on the spurs or shoots of the tree itself, in rubbish at the base of the tree, in hedgerows, dry ditches or any situation in or near the orchard which offers the type of protection needed. The adults do not seem to be affected by cold temperatures of winter except that they remain stationary, while on bright sunny days they can often be seen flitting about the trees.

The females normally lay their eggs between mid March and the petal fall stage. The eggs are at first almost colourless, but they soon turn to a clear lemon yellow and become deep yellow as they approach maturity. Hatching usually begins at the White Bud stage but may vary somewhat from season to season, depending on weather conditions.

The emerging nymphs are very delicate being almost colourless with large pinkish-red eyes, but after a few days the body colour changes to amber. Each is enveloped in a protective drop of transparent liquid. They feed in the developing leaves and flower trusses, and some of the blossoms may be actually killed. The honey dew secreted by the nymphs allows the growth of black sooty moulds and the presence of these gives the trees a very sickly appearance. Later in the season, serious downgrading of the fruits results if these black moulds are present on them.

The honey dew also attracts ants, flies and other insects, so that if these are found in large numbers on the tree one can be pretty sure that Pear Sucker is present.

Several instars occur before the nymphs become mature with the possession of wing buds. At the final moult, the young adult emerges.

There are normally three generations per year and occasionally a fourth generation.

Several observers have reported an apparent migration of some of the first generation adults. In some orchards where there has been a large first generation of nymphs, one can find really few individuals some time after the fruitlet stage has been reached. However, later in July, large numbers suddenly appear back in the orchard. This is thought to be more than just good concealment, but no alternative host plant has so far been found.

Serious damage to the trees is done late in the season by the nymphs of the third or fourth generations moving to the following years blossom buds. They seek shelter in the leaf stalk axils surrounding these buds, the tissues of which they feed upon. This feeding results in the appearance of many 'blind' buds the following season and over the years, if left unchecked, the cropping potential of an orchard goes down and down and down.

Now why has this pest suddenly come into prominence in practically all pear orchards within a short period?

One of the main contributory causes is no doubt the swing away from winter washes. While tar oil spraying does not give a complete control, it certainly keeps the population in any one orchard down to a low level by killing off any adults overwintering on the trees and providing an oily film over the surface of the spurs and shoots, which deters the females from laying their eggs. Of course, winter spraying did not control adults overwintering away from the trees, and so the pest was always present although often in small numbers.

Nicotine was formerly recommended for use at the white bud stage but this has now been superseded by the organo-phosphorus materials, for nicotine is a contact insecticide requiring a fairly high temperature (i.e. around 70° F.) to be really effective, whereas some of the organo phosphorus sprays have systemic as well as contact action which is not so dependent on temperature.

Good control may be obtained by using a material such as dimethoate, malathion or demeton methyl at the white bud stage and again at petal fall or, in seasons such as 1961 when virtually no eggs had hatched by the white bud stage, a first spray at petal fall and a second 14 days later. Where these early season sprays have not been applied and a build up of the pest occurs later in the season, the grower should apply an organo-phosphorus spray immediately after picking during a fine, warm period rather than wait until the following spring.

Little experience has been recorded with low volume sprays against this pest, but several instances have occurred where an organo-phosphorus material at the recommended dosage in 50 gallons of water per acre has given excellent control.

Another advantage of the organo-phosphorus materials over nicotine is that they also control Red Spider mites on pear, at least temporarily.

References

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